SUMMARY REPORT

OF THE

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

FOR THE CALENDAR YEAR

1916

PRINTED BY ORDER OF PARLIAMENT

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EXCELLENT MAJESTY
1917

To His Excellency the Duke of Devonshire, K.G., P.C., G.C.M.G., G.C.V.O., etc., etc., Governor General and Commander in Chief of the Dominion of Canada.

MAY IT PLEASE YOUR EXCELLENCY,—

The undersigned has the honour to lay before Your Excellency—in compliance with 6–7 Edward VII, chapter 29, section 18—the Summary Report of the operations of the Geological Survey during the calendar year 1916.

ES. L. PATENAUDE,
Minister of Mines.

To the Hon. Es. L. PATENAUDE, M.P.,
Minister of Mines,
Ottawa.

SIR,—I have the honour to transmit, herewith, the Summary Report of the operations of the Geological Survey for the calendar year 1916.

I have the honour to be, sir,

Your obedient servant,

R. G. McCONNELL,
Deputy Minister, Department of Mines.

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SUMMARY REPORT

OF THE

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

FOR THE CALENDAR YEAR 1916.

R. G. McConnell,
Deputy Minister of Mines.

Sir:

I have the honour to submit the following summary report on the operations of the Geological Survey for the calendar year 1916.

INTRODUCTORY STATEMENT.

The report that follows is intended to present in summary form an outline of the work carried on by the Geological Survey during the year 1916. As in the past, the work has been chiefly geological but includes topographical surveys and investigations in biology, ethnology, and archæology.

Owing to the destruction of the Parliament buildings by fire on the night of February 3–4, it was necessary to provide accommodation immediately for both branches of Parliament then in session. The Victoria Memorial Museum, occupied by the administrative offices of the Department of Mines and by the offices and Museum of the Geological Survey, was the most suitable building in the city for the purpose. Accordingly, on the morning of Friday, February 4, the task of packing and moving the large collections stored in the Exhibition halls of the Museum was begun and the House of Commons met in the auditorium on the afternoon of the same day; and the Senate in the west hall on the ground floor on the following Tuesday. The accomplishment of the change without, it is hoped, serious damage to the Museum specimens, was made possible by the hearty co-operation of the whole staff of the Geological Survey, both men and women, who laboured day and night until the work was done. The Public Works Department working concurrently, subdivided and prepared the building for its new use.

The administrative offices of the Department of Mines and the offices of the staff of the Geological Survey, excepting those of the palæontological, biological, draughting, and photographic divisions, and the library, were moved to temporary quarters in unoccupied buildings owned by the Government on the north side of Wellington street, just west of Bank street.

The wide separation of the staff and the storage of the Museum specimens has hampered the work of the department in many ways and it is most essential that quarters should be provided suitable to its needs and more worthy of a department of the government.

Although the operations of the Geological Survey have been somewhat curtailed owing to the conditions arising out of the war, it was realized that the work was of so great importance to the welfare of the country that its activities must not

be needlessly hampered. The explorations and investigations were directed, even more than in the past, along lines promising to lead to economic results and special work was done in the investigation of materials required for the prosecution of the war and in materials required in the industries, the supply of which had been cut off by the war.

The results of an exploration of coal-bearing lands lying north of the Grand Trunk Pacific railway, between Brûlé lake and Smoky river, in western Alberta, are of particular interest. Mr. MacVicar, who made the examination, found the coal to be of good quality and to occur in thick seams. The amount of coal in the area seemed to approximate that of the known coal reserves of Nova Scotia.

Contracts were let in the summer and early autumn for the boring of two test wells in the region lying south of the Canadian Pacific railway between Medicine Hat and Lethbridge. It is expected that the wells will show the presence of water over an extended area at a depth not too great to be reached by the farmers of the district. A report on the district by D. B. Dowling, on whose advice the wells were located, was published in the Summary Report for 1915.

In order to ensure closer supervision of geological parties in the field and to keep more closely in touch with the needs of the different parts of the country, the Dominion has been divided into districts, which have been placed for purposes of geological investigation, under the supervision of the following geologists:

E. R. Faribault, geologist in charge of Nova Scotia division.

G. A. Young, geologist in charge of Eastern Quebec and New Brunswick division.

W. H. Collins, geologist in charge of Pre-Cambrian (Ontario and Quebec) division.

D. B. Dowling, geologist in charge of Great Plains division.

C. Camsell, geologist in charge of Northern Exploration division.

O. E. LeRoy, geologist in charge of British Columbia division.

D. D. Cairnes, geologist in charge of Northern British Columbia and Yukon division.

The following members of the staff have joined the Overseas forces: O. E. LeRoy and S. J. Schofield, geologists; W. E. Lawson, S. C. McLean, A. G. Haultain, A. C. T. Sheppard, E. E. Freeland, and J. R. Cox, topographers; S. G. Alexander, draughtsman; L. N. Richard, relief map-maker; W. J. Wright and W. A. Bell, assistant geologists (temporary); W. H. Miller, assistant topographer (temporary); A. Cox and John Stotesbury, messengers; and W. Cross and J. M. Lefebvre, labourers. Of these, Mr. Sheppard and Mr. Richard after a period of training were found to be physically unfit and Mr. Haultain was invalided home suffering from shell shock. Five members of the staff, G. A. Young, Wyatt Malcolm, Robert Harvie, E. E. Freeland, and J. F. Lyons were loaned to the War Purchasing Commission, continuing with the Commission or with the Department of Militia until after the end of the year. C. H. Freeman has been assigned for topographic work to the Department of Militia and Defence.

The following changes have taken place in the staff during the year: J. Keele, geologist, was transferred to the ceramics division of the Mines Branch; G. J. MacKay, technical officer, resigned, and L. L. Bolton, mining engineer, was transferred from the Mines Branch to fill the vacancy; the death occurred of Joseph Paquet, draughtsman; and John Stotesbury was appointed messenger.

The explorations, surveys, and investigations of the department extended to every province of Canada. A brief summary statement of the work follows and somewhat longer individual reports are given on subsequent pages.

GEOLOGICAL FIELD WORK

A brief statement is given below of the work of the staff; the notes are intended to direct attention to the various matters of economic importance investigated and are arranged in the order of location of the main fields of work, from west to east.

D. D. Cairnes spent the greater part of the field season in the Klotassin area, southern Yukon. From one creek in this area between 500 and 600 pounds of wolframite concentrate has been obtained from the auriferous placer deposits. Mr. Cairnes visited Dublin gulch, Duncan Creek mining district, for the purpose of investigating the possibility of the occurrence of scheelite in the placer deposits, and reports that scheelite was found to be relatively quite abundant. He also spent a short time examining some of the Windy Arm mining properties which, during the past season, were being reopened. Two days were spent examining certain "alkali" deposits occurring along the Whitehorse-Kluane wagon road.

After his return in the autumn Mr. Cairnes, at the request of the Canadian Munitions Resources Commission, examined tungsten and zinc properties in New Brunswick and Nova Scotia. The zinc-copper-lead property visited in Nova Scotia is situated near the eastern coast of Cape Breton and is of a promising character.

C. W. Drysdale at the beginning of the field season spent a short time making a hasty reconnaissance in the vicinity of Anyox and Portland canal on the northern Pacific coast of British Columbia. This area has now been topographically surveyed by the Geological Survey, and the reconnaissance was made for the purpose of securing information required in order to formulate plans to govern the geological work it is proposed to undertake in this district which includes the Hidden Creek mine, now one of the largest copper producing mines in British Columbia.

Following this work, Mr. Drysdale spent a month in the Bridge River map-area, Lillooet district, continuing and completing the work of preceding seasons. He reports finding in this area, during the past season, an outcrop of magnesite measuring 52 feet by 48 feet; this and other outcrops of the same mineral, in their character and mode of occurrence, resemble the magnesite deposits of southern California which have proved to be economically important. Mr. Drysdale, in his report in this volume, calls attention to the various ways in which magnesite is employed and gives brief notes on other known deposits of this mineral in Canada. He also directs attention to the great quantity of volcanic ash or pumice that is available in the district and which is valuable as a polishing material when manufactured in the form of scouring soap, metal polisher, etc. He also examined, during a very brief visit, the molybdenite properties known as the Index group, which lie some miles southward from Lillooet.

Mr. Drysdale spent the latter part of the field season in the Slocan map-area, Ainsworth and Slocan mining divisions, for the purpose of completing the investigation of this area. Stimulated by the present high price of metals, mining and prospecting is being energetically carried on in this very important silver-lead-zinc district. Mr. Drysdale's present report is accompanied by a map and drawings indicating the positions of the most productive metalliferous belts and the locations of the main ore-bearing veins.

At the close of his summary report, Mr. Drysdale presents some very important observations bearing on the relative ages of various geological horizons as developed in Kootenay district.

D. B. Dowling in his report included in the present volume contributes information regarding the development of the coal, oil, gas, and artesian water resources of Alberta and Saskatchewan. Mr. Dowling visited the coal mines opened in the valley of Red Deer river at Drumheller and gives a description of a section

of the strata in this vicinity, together with notes on the various mines and on the three coal seams now being worked.

B. Rose during the past season continued his investigation of the coal-bearing and associated strata of southwestern Alberta. Mr. Rose's work, together with that of Mr. Stewart, completes the mapping of the Cretaceous coal areas situated south of latitude north 50 degrees and lying between longitude 144 degrees on the east and the main range of the Rocky mountains on the west. In the report in this volume, Mr. Rose deals with the western part of the above-mentioned area in which the coal of the Kootenay formation occurs.

S. E. Slipper during the past season continued his work of systematically collecting and correlating the data obtained from drillings made in the search for oil and gas in Alberta. During 1916, twenty standard drilling outfits were working in the foothills and in his report Mr. Slipper summarizes the work done in the various fields, giving information regarding production and character of oil and gas from various wells and also logs of some of the wells. In the case of the Medicine Hat and the Bow Island gas fields, Mr. Slipper presents a compilation of the more important available information regarding these two important fields and discusses the important question of the advisability of drilling shallow gas wells to afford power for pumping outfits required to irrigate the bench lands bordering the South Saskatchewan river from Medicine Hat to Rapid narrows.

J. S. Stewart visited a number of coal mines in the foothills of west central Alberta and in his report gives numerous details regarding their general conditions, development, etc.

J. MacVicar conducted an exploration of certain coal-bearing areas extending in the foothills from the vicinity of Brulé lake on the Grand Trunk Pacific railway, Alberta, northwestward. The coal measures are of Kootenay age and contain coal seams varying in thickness from a fraction of a foot up to 100 feet or more. Of these seams at least one may be classed as being anthracite.

F. H. McLearn made a study of the geological section exposed along Athabaska river, Alberta, from Athabaska Landing northward for 286 miles to a point a short distance below the mouth of Calumet river. Mr. McLearn, in his report in this volume, outlines some of the general conditions bearing on the possible occurrence of accumulations of gas and oil in the general district traversed.

C. Camsell spent the main part of the field season in an examination of the gypsum beds exposed on the lower part of Peace river, on Slave river, and on Salt river, northern Alberta. Mr. Camsell concludes that beds of gypsum occur over a very large area, probably to be measured in hundreds of square miles; he records exposed thicknesses as great as 50 feet; and states that an immense volume is favourably situated for mining. No evidence was found of the presence of beds of rock salt nor of potash salts in commercial quantities. Mr. Camsell also made an examination of the Moss molybdenite mine at Quyon, Quebec. This mine has been producing since the spring of 1916.

In behalf of the Canadian Munition Resources Commission Mr. Camsell examined and reported on the following tungsten properties: Burnt Hill Tungsten mine, York county, N.B.; Scheelite mine, Kaulback mine, and Waverley mine, Halifax county, N.S.

A. E. Cameron made a reconnaissance of the west arm of Great Slave lake, North West Territories. The shores of the west arm are underlain by Devonian strata, largely limestone, and practically all the outcropping limestones were found to be more or less bituminous and some on fracture gave distinct seepages of heavy petroleum. Mr. Cameron points out in his report that although much bituminous matter is present yet it is not certain that existing conditions are such

as to have permitted the accumulation of petroleum in quantities of economic importance.

F. J. Alcock carried out exploratory work in the region north of lake Athabaska, in Alberta and Saskatchewan. He devoted considerable attention to a series of rocks containing an iron ore-bearing formation, but as yet no deposits of iron ore of economic importance have been discovered.

A. MacLean examined the Estevan district in southeastern Saskatchewan, paying attention to questions relating to the occurrence of lignite, the development of the industries connected with the clay and shale deposits, and to the possible presence of natural gas.

R. C. Wallace geologically examined the southern part of Manitoba between Red river and the eastern boundary of the province.

E. L. Bruce continued work in the Amisk-Athapapuskow Lake area in northern Saskatchewan and Manitoba, where two important bodies of sulphide ore carrying gold and silver have been discovered. Mr. Bruce also paid a short visit to the Wekusko Lake district where considerable prospecting and some development work has been done in connexion with the gold-bearing quartz veins there developed.

J. A. Dresser spent a few weeks in the Rice Lake area, Manitoba. Considerable attention has been directed to this district situated in the neighbourhood of the headwaters of Wanipigow and Manigotagan rivers owing to the presence of many gold-bearing quartz veins. Numerous samples of the veins in all parts of the district, indicate that the gold is widely distributed.

W. A. Johnston investigated the agricultural possibilities of the Whitemouth River map-area in the extreme southeastern part of Manitoba. Although the greater part of this district is less than 100 miles from Winnipeg, much of the land has remained unsettled.

W. H. Collins completed his study of the Pre-Cambrian strata of the region bordering the north shore of lake Huron, Ontario.

T. L. Tanton made a reconnaissance of an area 177 miles long by 20 miles wide, in the districts of Sudbury and Algoma, along the line of the Canadian Northern railway from Gogama to Oba stations. Very little prospecting has been done in this district, but two large bodies of banded iron ore and various prospects yielding values in gold, copper, lead, etc., are recorded by Mr. Tanton who has mapped the distribution of the ore-bearing rocks.

J. Stansfield spent a short field season completing his study of the geology of the London district, Ontario.

M. Y. Williams completed his study of the Silurian strata of southwestern Ontario.

G. S. Hume investigated the Palæozoic strata present in the area bordering the north end of lake Timiskaming.

L. Reinecke conducted surveys in the search for material available for surfacing portions of certain main interprovincial roads in Ontario and Quebec. In Ontario this work was performed between Port Hope and Napanee, and along the route of the Rideau canal; in Quebec, in the counties of Argenteuil, Two Mountains, Soulanges, and Vaudreuil.

H. C. Cooke made a geological reconnaissance of the region including the headwaters of the Nottaway, Ashuapmuchuan, St. Maurice, and Gatineau rivers, northwestern Quebec.

J. Keele spent a few weeks in the northern part of Pontiac and Ottawa counties, Quebec, in the district drained by the tributaries of Gatineau river. In the present volume he gives a brief account of the general features of this comparatively unknown district.

M. E. Wilson made a special investigation of the magnesite deposits of Grenville, Quebec. When the supply of magnesite for American industries, which came almost entirely from Austria-Hungary and Greece, was cut off by the war, it was necessary to find sources of supply on this side of the ocean and the Grenville deposits became important as a source of supply for eastern America.

The deposits at Grenville are made up of intimate mixture of magnesite and dolomite in varying proportions and there are extensive masses in which the lime content ranges from 3 to 12 per cent. Mr. Wilson estimates that there are known deposits of magnesite in the district aggregating 750,000 tons averaging from 7 to 10 per cent lime.

Mr. Wilson made an examination also of a kaolin deposit in Amherst township, north of Grenville. The deposit is notable as being the only deposit of china clay at present mined in Canada. The examination indicates that a large quantity of kaolin is available and that it is well suited for the manufacture of china wares and, mined with marine clay, for the manufacture of firebricks.

R. Harvie being unable during the past season to continue the investigation of the Thetford-Black Lake area, Quebec, this work was carried on by J. K. Knox under the general supervision of Mr. Harvie. The field, of course, is of great importance since it includes the asbestos-mining area.

E. R. Faribault continued his work of mapping the "Gold-bearing" series of Nova Scotia. He completed the mapping of the Indian Garden and Caledonia map-areas, and of the Whiteburn gold district, and commenced field work on the Sable River and Lockeport map-areas.

A. O. Hayes during the field season examined the Londonderry iron ore deposits, Colchester county; a portion of the Nictaux-Torbrook iron ore district; various iron ore localities in Pictou and Antigonish counties; a magnesite occurrence at Orangedale, Inverness county; and other points in Cape Breton. Mr. Hayes also spent a short time examining a coal prospect at Maltempec, New Brunswick. He adds a short description of materials available for road construction in the vicinity of St. John, N.B.

Dr. A. P. Coleman made a geological exploration of the extreme northeastern part of Quebec and Labrador. Dr. Coleman found, in that hitherto unexplored, mountainous district, a most interesting series of Pre-Cambrian sedimentary rocks.

VERTEBRATE PALÆONTOLOGY.

L. M. Lambe during the past year was engaged chiefly in completing a popular guide book to the collections of fossil vertebrates and to the preparation of a memoir on the carnivorous dinosaur Gorgosaurus. G. F. Sternberg during the field season continued the exploration of the Edmonton dinosaur-bearing beds of Red Deer river, Alberta, and succeeded in making further valuable collections.

INVERTEBRATE PALÆONTOLOGY.

E. M. Kindle was engaged chiefly in office duties relating to the work of this section, but also spent a few weeks in the field in connexion with various problems.

L. D. Burling was engaged solely in office work.

A. E. Wilson assisted in various lines of work and with the assistance of E. M. Liddle and W. Cross continued the indexing of the collections of invertebrate fossils.

E. J. Whittaker continued certain lines of field work relating to the problems of sedimentation and of the conditions influencing the character of the present fauna of lake Ontario.

PALÆOBOTANY.

W. J. Wilson continued the work of studying new collections of palæobotanical materials and of cataloguing the old collections.

MINERALOGY.

R. A. A. Johnston during the year was largely engaged in answering inquiries regarding Canadian mineral occurrences.

E. Poitevin spent a part of the summer collecting mineral specimens in Quebec, New Brunswick, and Nova Scotia.

A. T. McKinnon spent a part of the field season gathering materials for the educational collections of minerals. The demand for these collections increased very largely over that of the preceding year.

BORINGS DIVISION

E. D. Ingall, together with J. A. Robert, continued his work of collecting records of boring operations throughout Canada and of furnishing information necessary to the prosecution of boring operations.

CANADIAN ARCTIC EXPEDITION.

The southern party of the Canadian Arctic Expedition, made up principally of officers of the Geological Survey, returned to Ottawa during the summer of 1916. The main portion of the party, including R. M. Anderson, zoologist, in charge, J. J. O'Neill, geologist, and J. R. Cox, topographer, came out on the vessel Alaska, landing at Nome, Alaska, on August 15, 1916. K. G. Chipman, one of the topographers, leaving the ship's party at the mouth of Coppermine river on June 1, returned by way of Great Slave lake and Mackenzie river, and arrived at Peace River crossing on August 18.

On their arrival at Ottawa Mr. Anderson, Mr. O'Neill, Mr. Chipman, and Mr. Cox took up their duties in the office, and Diamond Jenness and Frits Johansen who had been attached to the party as ethnologist and marine biologist respectively, were temporarily employed to put into shape the notes and materials they had collected. The expedition has added materially to our knowledge of the geography, geology, and natural history of the Arctic, and has yielded, as was hoped, economic results of importance. Chief among these is the knowledge gained of the area of copper-bearing rocks of Coronation gulf investigated by Mr. O'Neill. The exploration shows that copper-bearing lava flows over an extensive area and that there is a probability of the occurrence there of deposits of copper that may be worked, even with the great handicap of their remoteness and the severity of the climate. Full accounts of the results attained by the expedition will be made public in a series of monographs which will be issued in due time.

TOPOGRAPHICAL DIVISION.

F. S. Falconer topographically surveyed the Anyox map-area, British Columbia.

D. A. Nichols mapped the Kananaskis-Elbow map-area, British Columbia and Alberta.

A. C. T. Sheppard mapped the Eastend map-area, Saskatchewan.

C. H. Freeman made surveys of various lakes and rivers in the vicinity of Foleyet on the Canadian Northern Ontario railway.

B. R. MacKay mapped the Beauceville map-area, Quebec.

R. C. McDonald was engaged in extending northward the Rocky Mountains coal field area triangulation.

BIOLOGICAL DIVISION.

Botany.

John Macoun spent the year collecting and studying the cryptogams of Vancouver island, B.C., chiefly of Saanich peninsula and the vicinity of Victoria.

J. M. Macoun during the winter was chiefly engaged in the routine work of the section. The field season was chiefly spent making botanical collections in British Columbia, at Brackendale, Howe sound, and near Lillooet.

F. J. Lewis spent the field season in the vicinity of Banff, making a large collection of botanical specimens and mapping the Banff National park for the purpose of illustrating the areal distribution and relations of the various components of the local flora.

F. Johansen since his return with the Canadian Arctic expedition has been engaged on work in connexion with his botanical collections made in the north.

Zoology.

P. A. Taverner was chiefly engaged in routine work of the division, such as correspondence and work connected with the care of incoming and other material.

C. H. Young spent the field season collecting zoological specimens in the vicinity of Brackendale, near Howe sound, and near Lillooet, B.C.

C. L. Patch, besides preparing material for the Museum, spent part of December, 1915, and January, 1916, at Barkley sound, Vancouver island, securing specimens of sea lions and winter sea birds.

Entomology.

C. Gordon Hewitt, Dominion Entomologist, has made progress in the identification and classification of the collections of insects. Valuable accessions to the collections were secured during the year mainly from the Arctic and British Columbia.

ANTHROPOLOGICAL DIVISION.

Ethnology and Linguistics.

E. Sapir besides supervising the work of the division, continued work on materials collected during 1915 and 1916.

C. M. Barbeau spent about three months in Charlevoix and Chicoutimi counties, Que., collecting French Canadian folk-lore.

F. W. Waugh spent about three months among the Ojibwa of northern Ontario and obtained much information regarding material culture, folk-lore, and medicine.

P. Radin continued his work upon Ojibwa data secured during previous years.

J. A. Teit during the past year has practically completed for publication his extensive series of Tahltan and Kaska mythological tales.

D. Jenness since his return with the Canadian Arctic expedition has begun to prepare his anthropological report on the Eskimo of northern Alaska and on the Copper Eskimo of Coronation gulf and vicinity.

Archæology.

H. I. Smith during the past year was engaged chiefly with work in connexion with archæological materials already collected.

W. J. Wintemberg did a small amount of field work in connexion with Iroquoian village sites in Ontario near Aylmer, Elgin county, and near London.

Physical Anthropology.

F. H. S. Knowles continued various lines of work connected with physical anthropology.

GEOGRAPHICAL AND DRAUGHTING DIVISION.

C. Omer Senécal reports the completion of 33 new maps during the year, while 28 more are in various stages of preparation. During the year a large number of sketch maps and other drawings were also prepared by the division.

PHOTOGRAPHIC DIVISION.

G. G. Clarke and the staff of his division performed the large amount of photographic work such as developing, printing, enlarging, and copying, resulting from the work of other divisions.

LIBRARY.

M. Calhoun reports that during the year the library staff besides taking care of new publications as received, also made progress in the general work of indexing and eataloguing the contents of the library.

DISTRIBUTION DIVISION.

The Geological Survey, in addition to the Annual Summary Report of the year's operations, publishes more extended reports from time to time as the work is completed, on particular areas and subjects.

These reports include memoirs and bulletins relating to geology, biology, and anthropology, and are distributed to the principal libraries, universities, and educational institutions in Canada, and to many institutions outside Canada.

Notices are also sent of all reports published to a large number of individuals, at intervals of about a month, and to these the reports are mailed on request.

Wyatt Malcolm, in charge of the distribution division, reports that during the year 1916, 61,595 publications, exclusive of French editions, were distributed and that of these, 36,411 publications were distributed in compliance with written or personal requests, and 25,184 were sent to addresses on the mailing list.

Marc Sauvallé, chief of the publishing and translating division, reports that during the year 1916, there were distributed 46,145 copies of French editions of publications, of which 22,685 were furnished in compliance with written or personal requests, and 23,460 were sent to addresses on the mailing list.

MUSEUM.

The geological and natural history museum was maintained at the Victoria Memorial Museum until the building was vacated to provide accommodation for the meetings of Parliament. As a part of the activities connected with the Museum, the series of popular lectures by officers of the Geological Survey staff was continued and proved increasingly popular among the teachers and scholars of the Public schools. H. I. Smith who had the arrangements in charge was able to carry out the following programme before the temporary quarters used for the purpose were taken over by Parliament.

"Illustrated lectures on topics relating to the work of the Museum were given last year in an improvised lecture hall on the upper floor of the Victoria Memorial Museum building, pending the completion of the large lecture hall built for the purpose. These lectures were continued throughout the 1915-16 season. This lecture hall had to be abandoned on February 4, owing to the occupation of the building by Parliament on the day following the destruction of the Parliament building. After this authorization was secured for continuing the lecture work in such auditoriums as might be provided by the organizations desiring lectures.

The organizations asking for the lectures chose both the topic and time, sometimes selecting the topic from those listed by us and at other times suggesting a topic of their own.

The topics of the various lectures delivered and the names of the lecturers are as follows: "Birds", by C. Patch; "Winter birds", by Miss W. K. Bentley; "Birds nests", by C. Patch; "The sea birds of Bonaventure island", twice by L. D. Burling; "Where animals spend the winter", six times by C. Patch; "Museum work at the capital of Canada", five times by Harlan I. Smith; "Efficiency", by L. D. Burling; "Indians", twice by F. W. Waugh and once by Harlan I. Smith; "Hunting Indians with an artist", twice by Harlan I. Smith; "Five North American nations, conquerors of the snow, forest, desert, mist, and plains", by Harlan I. Smith; "Indian houses", by F. W. Waugh; "Indian traps and trapping", by F. W. Waugh; "Indian games", by F. W. Waugh; "Indian music and musical instruments", by F. W. Waugh; "Indian tools and working methods", by F. W. Waugh; "Eskimo customs", by F. W. Waugh; "Indian methods of transportation by water", by F. W. Waugh; "Snowshoes", by F. W. Waugh; "Fire making", by F. W. Waugh; "Iroquois customs and beliefs", by F. W. Waugh; "Ranch life in the west", by Harlan I. Smith; "Irrigation", three times by Harlan I. Smith; "Minerals", six times by R. A. A. Johnston; "Rocks", four times by L. D. Burling; "Fossils", twice by L. D. Burling; "Mines and minerals of Ontario", by Eugene Poitevin; "How mountains are made", by L. D. Burling; "The geology of the Ottawa valley", by L. D. Burling; "The history of a lump of coal", by L. D. Burling; "The history of an iron pot", twice by A. O. Hayes; "The work of water", twice by E. M. Kindle; "Erosion", by E. M. Kindle.

Lantern slides were loaned for free educational purposes four times and moving picture films were loaned three times. Twenty-six slides illustrating economic birds were loaned to H. M. Speechly, Pilot Mound, Manitoba. Fifty-three illustrating the sea birds of Bonaventure island, Quebec, were loaned to Mr. Frank C. Hennessey to illustrate his four lectures at Albion College, Albion, Michigan. Thirty-five illustrating the work of the Museum were loaned Mr. William McIntosh, Curator of the Museum of the Natural History Society of New Brunswick, at St. John.

A set of slides illustrating common birds was loaned to Mr. W. E. Saunders for a bird lecture in Hamilton. The Museum's moving picture film of "The sea birds of Bonaventure island" was loaned to the Ottawa Humane Society.

This film and the film illustrating Mr. Jack Miner's wonderful success in conserving wild geese were loaned to Mr. W. E. Saunders.

The results so far obtained seem to indicate that this effort to interpret and spread the results of the work of the Geological Survey and Museum is much appreciated. For instance, one lecture topic was asked for nine times, another six times. As a partial outgrowth of this work the Cartier Street school has arranged an auditorium for the use of a lantern, secured a lantern, and arranged for the use of lantern pictures. The direct educational value of the lectures warrants the continuation of the work and the hope that the local experiment may ultimately result in the distribution of lectures, lantern slides, and moving picture films throughout Canada."

In connexion with the educational work, also, the zoological division prepared cases illustrating by mounted specimens various branches of natural history. The cases were of a size to be easily handled and were transferred successively to different city schools and seemed to be of great assistance in interesting the scholars in elementary science.

Many additions have been made to the Museum during the year by presentation, for which suitable acknowledgment is made in the following pages. Among these is a white marble bust of the late Sir William Logan, founder and former director of the Geological Survey. The bust, which is the work of Marshall Wood who also executed the statue of Queen Victoria in the library of Parliament and designed the ornamental railing and gates in front of the Government buildings, was placed in the library on January 28, 1916. It was for many years in the library of Parliament and was handed over to the Geological Survey through the courtesy of Dr. M. J. Griffin, Parliamentary librarian.

GEOLOGICAL REPORTS.

INVESTIGATIONS AND MAPPING IN YUKON TERRITORY.

(*D. D. Cairnes.*)

GENERAL INTRODUCTION.

The greater part of the last regular field season was spent in Klotassin area, southern Yukon; and a topographical and geological party was engaged there the entire summer. The area, including over 1,200 square miles, was mapped as to geology and drainage, and a special study was made of the mineral resources.

During the early part of August, the writer left camp in Klotassin area, went to Whitehorse, and from there spent two days examining and sampling certain saline incrustations which occur along the Whitehorse-Kluane wagon road, and which, it was thought, might contain important amounts of potash.

Later in the season the writer again left Klotassin area and spent a few days in Mayo area where the tungsten deposits in the vicinity of Dublin Gulch were investigated, and a deposit of shell marl near Mayo was examined.

William E. Cockfield was senior assistant in connexion with the work in Klotassin area, and took charge of the field work there during the writer's absence.

At the close of the regular field season, a few days during the early part of October were spent examining lode deposits in the Windy Arm district.

Reports of the work in these four districts follow:

Tungsten Deposits of Dublin Gulch and Vicinity, Y.T.

GENERAL STATEMENT.

During the past summer, while engaged in geological and topographical work in Klotassin area, Yukon Territory, the writer obtained information through the Government assay office at Whitehorse, indicating the possibility of the occurrence of important deposits of scheelite on Dublin gulch. As the ores of tungsten are at present greatly in demand in connexion with the manufacture of munitions, arrangements were made at once to visit the locality. Accordingly, early in September a few days were spent in the vicinity of Dublin gulch, and it was found that scheelite occurs not only in important amounts in the stream gravels along Dublin gulch and some of its tributaries, but also in lode deposits which may prove to be of economic importance.

During the entire course of the investigation in Dublin gulch and in that vicinity, the writer was ably and voluntarily assisted by Mr. Robert Fisher, a miner and old-time resident in the district, and to him the writer wishes to express his sincere gratitude for information afforded, and for actual work performed.

GEOGRAPHICAL POSITION.

Dublin gulch lies within Duncan Creek mining district, in the part known as Mayo area[1]. It is a small stream about 4 miles long, and empties into Haggart

[1] Cairnes, D. D., "Mayo Area", Geol. Surv., Can., Sum. Rept., 1915, p. 10.

creek, joining it from the northeast about 14 miles from its mouth. Haggart creek is one of the principal tributaries of McQuesten river, and has a length of over 20 miles (Figure 1).

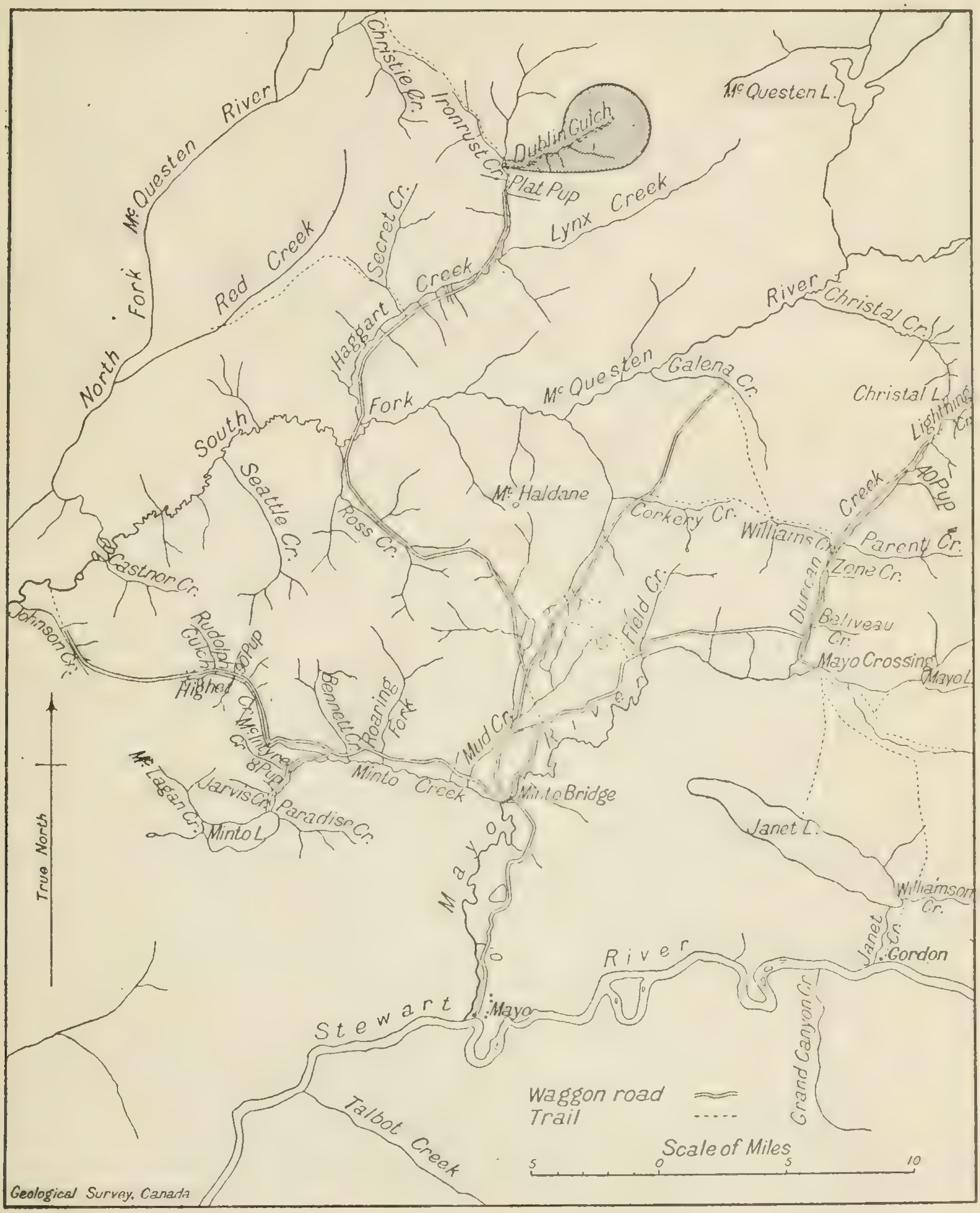

Figure 1. Mayo area, Yukon Territory. Location of scheelite-bearing area on Dublin gulch shown by shading.

TRANSPORTATION AND ACCESSIBILITY.

Mayo area, in which Dublin gulch is situated, is fairly readily accessible. Stewart river generally opens between May 10 and 15, and remains clear of ice until some time in October. During the season of open navigation, a steamer with good passenger and freight accommodation makes weekly trips from Dawson

to Mayo, a distance of 238 miles. During the winter months, there is a monthly —and for part of the time, a bi-monthly—overland stage service between Dawson and Minto Bridge, a small village 10 miles north of Mayo, at the junction of Minto creek and Mayo river. The distance from Dawson to Minto Bridge over the stage road is 174 miles. Mayo and Minto Bridge thus are the distributing points for Mayo area. From Mayo, a good wagon road has been constructed by the Yukon Government, to Minto Bridge, with a branch extending to the mouth of Dublin gulch, a distance of 35 miles, or 45 miles from Mayo; but for only about 6 miles of the 35, is the road good enough for summer freighting. For the remainder of the distance the road is so rough and soft it is almost impossible to drive over it in summer, even with a light buckboard. Thus all freighting over this road must necessarily be done in winter when it would probably cost about $35 or $40 per ton to take concentrates or ore from Dublin gulch to Mayo. From Mayo, ore has recently been shipped to San Francisco by the all-water route via St. Michael for about $22 per ton, so the rate to Vancouver would be between $15 and $20 per ton. The regular rate charged by the Side Streams Navigation Company on in-going freight from Dawson to Mayo is 2 cents per pound.

HISTORY.

Dublin gulch with the immediately surrounding portion of Yukon Territory has been reported upon at different times. In 1904, Joseph Keele, of the Geological Survey, made a reconnaissance survey and geological examination of a portion of Duncan Creek mining district including Dublin gulch.[1] In 1912, Mr. T. A. McLean, on behalf of the Mines Branch of the Department of Mines, examined the lode deposits on Dublin gulch.[2] In 1915, the writer made a preliminary examination of Mayo area, including Dublin gulch, with the expectation of completing the investigation the following summer.[3] Keele mentions the presence of scheelite on Dublin gulch. He states, "The gold on Dublin gulch ....is accompanied by a quantity of heavy white sand, consisting of rounded grains of scheelite (tungstate of lime), from which it is difficult to separate the gold."[4] Hoffmann[5] examined and described the material collected by Keele. The placer miners of that vicinity, although they knew that what they termed "grey sand" occurred on Dublin gulch in considerable quantities, did not know its value, and recognized it only when it was obtained in the sluice boxes, in a finely comminuted condition. For this reason, many tons of rich tungsten ore concentrates have no doubt been lost in the placer mining operations along this creek.

In 1898, John Suttles commenced placer mining on Dublin gulch, and he continued to work more or less each summer until the autumn of 1915, during which time, it is estimated by the old-timers in that locality, that he must have recovered in all between $45,000 and $50,000 in gold. On August 30, 1905, a concession for placer mining on Dublin gulch, generally known as the W. E. Thompson concession, was granted and recorded as hydraulic mining lease No. 47. This is described as follows:

> "All and singular that certain parcel or tract of land situate, lying and being in the Yukon Territory on Dublin creek, described as follows: Commencing at a point on said creek 1,360 feet more or less, up stream from its junction with Haggart creek, a tributary of the McQuesten river, thence up said Dublin creek 3·21 miles, more or less, with a width of one-half mile on each side, excluding thereout and therefrom any placer mining claims for which entries may

[1] Keele, Joseph, "The Duncan Creek mining district", Geol. Surv., Can., Sum. Rept., 1904, pp. 18A–42A.
[2] McLean, T. A., "Lode mining in Yukon", Mines Branch, Dept. of Mines, Can., 1914, pp. 127–159.
[3] Cairnes, D. D., "Mayo area", Geol. Surv., Can., Sum. Rept., 1915, pp. 10–34.
[4] Keele, Joseph, op. cit., p. 33A.
[5] Hoffmann, G. C., Geol. Surv., Can., Ann. Rept., vol. XVI, 1904, p. 340A.

have been granted, and which may be in force on the day of these presents, as shown on plans of survey thereof dated the 30th of November and the 7th of December, 1903, signed by George White-Fraser, D.L.S., and of record in the Timber and Mines Branch of the Department of the Interior."

Previous to the granting of this concession, John Suttles had located about 2,500 feet of Dublin gulch, near the lower end of what afterwards became the concession, and this ground was not, therefore, included in the grant. Practically all the placer mining that has been done on Dublin gulch has been on the Suttles claims. Accordingly, as the owner of the concession did not work his ground as required by the terms of the lease the concession was cancelled and steps have been taken to throw the ground open to the public. Since it has become known that scheelite occurs in important amounts on Dublin gulch, a number of placer claims have been staked on its tributaries outside the boundaries of the concession. Also some lode claims supposed to cover deposits of scheelite have been recently located.

Between the close of the summer season of 1915, and the opening of the past season (1916), the holdings of John Suttles on Dublin gulch were acquired by Cantin Bros., who mined the ground during the past summer. They worked by ground sluicing, and with three men working, cleaned up altogether about $6,000 in gold. They commenced to systematically save the scheelite concentrate after the writer's visit, and report that since that time, they have been able to recover about 400 pounds a week, with very slight additional time or labour.

GENERAL GEOLOGY AND TOPOGRAPHY.

Mayo area lies entirely within the Yukon plateau physiographic province, and is mainly characterized by being subdivided by well developed, flat-bottomed, interlocking valleys, into numerous small, isolated mountain groups and areas of well dissected upland. The higher summits rise to elevations of from 5,000 to over 6,500 feet above sea-level—Mayo village being considered to be 1,625, and Mayo lake 2,000 feet above the sea. The former plateau surface has been largely destroyed in this district, and the shapes of the land forms, except where modified by glaciation, are for the most part dependent on the geological formations. The district has been, on the whole, intensely glaciated, the glacial ice, at one time, extending over practically the entire area, and enveloping all except possibly the highest summits. As a result, the valley walls have become smoothed, planated, and steepened, giving to the valleys, typical U-shaped cross-sections. In addition, the floors of the master valleys have become deeply covered with glacial detritus, which in post-Glacial time has been trenched and in part removed by the streams of the district.

In the vicinity of Dublin gulch quite extensive stretches of gently rolling upland are preserved which have a general elevation of about 1,900 feet above the mouth of Dublin gulch. Potato hills at the head of Dublin gulch are somewhat higher, and are estimated to rise to 5,400 feet above sea-level. The valley of Dublin gulch has been considerably modified by glacial action, thus the creek gravels in the valley bottoms contain more or less foreign material. The upland in this vicinity, and even the upper portions of the valley walls, on the other hand, have been only slightly affected, and foreign pebbles or boulders are there somewhat exceptional.

The geological formations exposed throughout the greater part of Mayo area are dominantly old, metamorphosed sediments, including mainly mica schists, quartz schists, and schistose quartzites, with also some beds of crystalline limestone. These correspond to certain of the old, schistose rocks of the Klon-

dike,[1] and other portions of Yukon and Alaska, and belong to the Yukon group[2] which is thought to be of Pre-Cambrian age. In the vicinity of Dublin gulch, a small granitic batholith some 3 or 4 miles in length cuts these older rocks, and includes all the upper portion of the creek and its upper tributaries. This granitic intrusion is composed mainly of grey biotite granites, thought to be of Mesozoic age.

TUNGSTEN.

In the vicinity of Dublin gulch, the principal tungsten-containing mineral that has so far been found is scheelite. Occasional particles of wolframite were also noted in the concentrates obtained in the placer mining operations there, but this mineral does not occur in amounts of much economic importance.

Scheelite ($CaWO_4$) is calcium tungstate, and contains 80·6 per cent of tung sten trioxide (WO_3), and 19·4 per cent of lime. It has a hardness of 4·5 to 5, i.e., it is about intermediate in hardness between calcite and an average feldspar. Its lustre is vitreous inclining to adamantine, and its colour is generally white, yellowish white, or pale yellow. Brownish, greenish, and reddish varieties occur, but are rare. The scheelite of Dublin gulch is white to pale yellow in colour. Possibly the most diagnostic physical property of scheelite is its specific gravity which is 5·9 to 6·1, or considerably higher than that of magnetic iron ore.

Wolframite is the tungstate of iron and manganese. Its hardness is 5 to 5·5, its specific gravity is 7·2 to 7·5, and its colour is dark greyish or brownish black. The streak is nearly black. Wolframite is generally readily recognizable by the brillant sub-metallic lustre, on its characteristically perfect cleavage faces. It much resembles specular hematite, but is much heavier.

In describing tungsten and its uses, Dr. Walker in his report published in 1909, states: "Tungsten is one of those rare metals which have become generally useful during the last few years. Formerly it was of interest chiefly because it was one of the rare chemical elements. Of late it has become an article of commerce and industry, and has attracted much attention on the part of iron masters, dyers, silk workers, electricians, and especially of those connected with the mining industry. Being one of the most infusible metals known it has been recently employed in the manufacture of incandescent electric lamps. The tungsten filament has the advantage over the ordinary carbon filament of yielding a much whiter light. When carbon filaments are heated to a brillant white, a black smoky deposit of volatilized carbon forms upon the interior of the bulb so that much of the light efficiency is lost; while the tungsten lamp will stand this white incandescent condition without any appreciable deterioration. Apart from this advantage, the manufacturers of the tungsten bulbs claim for their product a greater light efficiency for the electric energy consumed, even when compared with new, undimmed carbon bulbs. Considerable quantities of tungsten are consumed in the manufacture of tungstates, which are used as a mordant in dyeing, in giving weight to silk goods, and in rendering cotton fabrics fireproof. The chief demand for tungsten, however, is for the production of tungsten steel, which is also called wolfram steel. The addition of a small percentage of this metal increases the elastic limit and tensile strength. Tungsten steel is self-hardening, so that no special skill is required on the part of the blacksmith in the sharpening of tools made from it. Tools which have been heated are found to be well tempered as soon as they cool. These properties make this alloy very desir-

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[1] McConnell, R. G., "Report on the Klondike Gold Fields", Geol. Surv., Can., Ann. Rept., vol. XIV, pt. B, 1905, pp. 12B–15B.

[2] Cairnes, D. D., "The Yukon-Alaska International Boundary between Porcupine and Yukon rivers", Geol. Surv., Can., Mem. 67, pp. 38–44, 1914.

able for high speed tool steel."[1] Since the war there has been a great demand for tungsten for use in the manufacture of high speed cutting tools employed in the manufacture of munitions.

At the beginning of the war, the Imperial Government placed a price on all tungsten ores within the British Empire, and prohibited their export. The price paid per gross ton (2,240 lbs.) of 65 cent per WO_3 ore is at the rate of 55 shillings per unit (1 per cent of 2,240 lbs.) per gross ton f.o.b. Liverpool, less charges as per H. A. Watson's pro forma contract. The price thus fixed amounts to about $853 per ton without considering insurance or freight. A penalty of 6 cents per unit down to 60 per cent WO_3 is imposed.

ECONOMIC INVESTIGATION.

Investigating the occurrence of scheelite on Dublin gulch, and prospecting for its source, were at first found difficult, owing to the fact that scheelite is not a readily recognizable mineral, especially when finely subdivided. In places it is even difficult to distinguish from quartz, feldspar, or other white or nearly white minerals. Therefore, in addition to the ordinary physical, chemical, and specific gravity tests, panning was found to be a very efficient and rapid auxiliary method for detecting this mineral either in gravel, or pulverized rock or ore material. Owing to its high specific gravity, very minute particles of scheelite can be saved by panning almost as readily as gold, and can then be easily identified.

It was found that the stream gravels along Dublin gulch contain important amounts of scheelite. Scheelite also occurs below the mouth of Dublin gulch in the gravels of Haggart creek, for some distance, but not to nearly the same extent as along Dublin gulch, from where it is clear, practically all of the mineral is derived.

Previous to the writer's visit, the mineral scheelite, as such, was quite unknown to the miners of Dublin gulch and vicinity, but the so-called "grey sand" which collected in the sluice boxes, and was difficult to dispose of, had recently been discovered to be of value and some had been saved. Also, places were found where this "grey sand" had been dumped from the sluice boxes in past years. Altogether, about a ton was found to be available. Two samples (A and B) of these concentrates were taken. No. A is a sample from a pile containing about 300 pounds, which was dumped where it lay, several years ago. This sample was assayed at the ore testing plant of the Department of Mines, Ottawa,[2] and was found to contain 68 per cent WO_3 (tungsten trioxide). No. B is a sample from a lot of about 800 pounds of concentrates that had been recently collected. This was assayed and found to contain 66·30 per cent WO_3. Associated with the placer gold and scheelite, there occurs a certain amount of heavy, dark concentrate including wolframite, cassiterite (tin stone), hematite, and garnet. These minerals when plentiful are somewhat difficult to separate from the scheelite in the sluice boxes. When visited in September Cantin brothers had saved about 200 pounds of this dark concentrate, and a sample from this was assayed and found to contain 61·20 per cent WO_3.

About 2 miles of Dublin gulch that is adapted to placer mining is still virgin ground, and should yield gold and scheelite in somewhat similar amounts to the 2,000 feet or so that have been worked. Along the part of the creek that has been mined, the gravels and overburden are, together, in most places, from 6 to 20 feet in thickness. The upper portion of Dublin gulch, commencing about

[1] Walker, T. L., "Report on the tungsten ores of Canada", Mines Branch, Dept. of Mines, Can., 1909, pp. 3, 4.
[2] All assays, the results of which are given in this report, were made at the ore testing plant of the Department of Mines, Ottawa.

2½ miles from its mouth, could not be worked by ordinary placer methods owing to the fact that the valley bottom is strewn with vast quantitites of a coarse granite talus, many of the individual blocks being as much as 6 to 20 feet in diameter. In addition to the main creek, it will probably be found that some of its tributaries will pay to mine, now that scheelite is known to occur in this vicinity in addition to the gold.

An attempt was made to determine the bedrock source of the scheelite. It was found that all gravels derived from the granitic rocks in the vicinity contain important amounts of this mineral, although no scheelite could be detected in the ordinary unaltered granite. Well up on the hillsides, and even on the upland, where the ordinary more or less decomposed granitic overburden is practically in place and unconcentrated it contains scheelite in appreciable amounts. The schistose rocks, on the other hand, yield little if any of this mineral. Places were found near the heads of some of the smaller tributaries of Dublin gulch, where the gravels of granitic origin yielded as much as 1 per cent scheelite or over one pound of scheelite concentrate from 100 pounds of gravel. A sample of about one pound of scheelite concentrate, obtained in panning four pans of gravel near the head of Bum Boy gulch, was assayed and found to contain 63·80 per cent WO_3. The total amount of scheelite in the vicinity must, therefore, be very great. In places even near the extreme heads of some of the smaller tributary streams where water is rather scarce, it is estimated that men working with rockers or cradles could make more than wages from the scheelite alone.

There are a number of important gold-bearing quartz veins in this vicinity[1], some of which have been quite extensively developed. It was at first thought that the scheelite might be associated with these veins, but little or none was found in them. Scheelite was eventually found at one point with its original associations, and there the bedrock was covered by several feet of overburden, making prospecting slow and difficult. At that point the scheelite is associated with small, barren, ramifying quartz veinlets which occur very plentifully intersecting pegmatitic zones within the granite. The scheelite, where found, occurs in the form of crystals along the edges of and between the veinlets, the individual crystals being as much as 0·3 to 0·5 inches in length. In all probability this is the manner in which most of the scheelite of the district occurs. It is quite possible, with further prospecting and investigation, that zones will be found in this vicinity which will pay to work as lode deposits. A sample of vein material from this locality recently forwarded to the writer by Robert Fisher was assayed at the ore testing plant in Ottawa and found to contain 5·70 per cent WO_3, which is indeed very promising.

SUMMARY AND CONCLUSIONS.

Two main factors will somewhat retard the rapid development of mining on Dublin gulch and in that vicinity; these are the limited water supply for placer mining, and the remoteness of the district. The extent of the placer mining operations will be always limited by the available supply of water. However, by conserving and making the most economical use of all the water in Dublin gulch and its tributaries, very much more work can be done than has been done in the past. Owing to the remoteness of the district, also, it is difficult and expensive to freight in supplies and equipment, and the output of scheelite or other ores can at present be freighted out only during the winter when the sleighing is good. The cost of building a suitable summer road is at present, at least,

[1] McLean, T. A., "Lode mining in Yukon", Mines Branch, Dept. of Mines, Can., 1914, pp. 127–159.
Cairnes, D. D., "Mayo area, Yukon Territory", Geol. Surv., Can., Sum. Rept., 1915, pp. 29–33.

almost prohibitive. This means that the scheelite concentrates which were mined during the summer of 1916 will be freighted to Mayo during the following winter and will not be available until after navigation opens in the early summer of 1917; and that concentrates recovered during the summer of 1917 will not be available until the summer of 1918.

During the writer's visit to Mayo area, every effort was made to instruct the miners and prospectors of the district in the physical characters of the tungsten minerals and the simple tests for determining them; also specimens of scheelite and wolframite were distributed to those most interested.

Between $1\frac{1}{2}$ and 2 tons of scheelite concentrates, similar to those sampled, should be freighted to Mayo this winter, and be available early next summer. Next season, also, when the concession on Dublin gulch has been thrown open for staking, if the locators work diligently throughout the season, it is reasonable to expect that at least between 10 and 20 tons of tungsten concentrates in addition to the gold will be recovered. In fact, it would now appear as if Dublin gulch is destined to become an important Canadian source of tungsten ore.

Marl Deposit Near Mayo.

While waiting at Mayo for a steamer in September, 1916, the writer examined a greyish deposit of shell marl exposed around a lake in the vicinity. The lake lies along the wagon-road running from Mayo to Minto Bridge, and is about 2 miles from Mayo. The level of the water is being gradually lowered as the drainage of the district becomes integrated, and the lake is gradually filling with marl which has resulted from the accumulation, and more or less complete disintegration of many generations of freshwater shells, the marl being exposed all around the lake, and on the islands within it. The area covered by the water and the marl rim is apparently between 1 and 2 square miles. The marl deposit is very soft, and is apparently thick as it is possible at the water's edge to easily push a stick down into it to a depth of 10 feet. Evidently, the entire lake is underlain by the marl which may also extend farther back from the water's edge than appears. Around the lake, a reddish, clayey soil, several feet in thickness, extends back for about a mile beyond the marl rim.

Four samples of the marl and soil were taken. These were air-dried and analysed, with the following results:

Analyses of Marl and Soil from Mayo.

	I	II	III	IV
Moisture	16·00	9·04	5·66	4·75
Organic and volatile matter	23·51	24·03	1·66	1·34
Mineral matter insoluble in acid	6·55	6·75	24·91	36·60
Carbonate of lime	49·90	54·39	53·19	45·91
Undetermined	4·04	5·79	14·63	11·40
	100·00	100·00	100·00	100·00
Nitrogen, in organic matter	0·84	0·75	0·16	0·20

I. Surface sample of marl, taken near the water's edge, and containing many small shells.
II. Sample of the upper 3 feet of the marl.
III. Sample of the reddish, clayey soil, a few feet back from the water's edge and the grey marl rim, and containing apparently no shells.
IV. Sample of the lighter, reddish soil, higher up and less closely associated with the marl.

Analyst, Dr. Frank T. Shutt, Dominion Experimental Farm, Ottawa.

Dr. Shutt states: "Traces only, of phosphoric acid were detected in all the samples. All four samples are marl of fair quality, the carbonate of lime content approximating 50 per cent. Their agricultural value would, therefore, be in furnishing lime for soils deficient in this element and in correcting soil acidity. Samples I and II also contain notable amounts of vegetable matter and nitrogen and their application would, therefore, prove useful for all types of soil more or less poor in these important soil constituents."

This marl is too impure to be of value for the manufacture of cement, but is of considerable importance for agricultural purposes, and in Mayo area and adjoining portions of Yukon, agriculture, it is hoped, will in the near future be followed much more extensively than at present, as wide tracts of valley lands are well adapted to agricultural pursuits.

The part played by lime and its compounds in maintaining and increasing soil fertility is an exceedingly important one; and, chiefly because they may be readily and uniformly distributed over the land, the marls constitute a very useful form of carbonate of lime for agricultural purposes, and one the value of which Canadian farmers have not yet sufficiently recognized. The functions and use of marl in agriculture, and also some methods of testing for acidity in soils are described in a bulletin,[1] which may be obtained from the Director, Experimental Farms, Ottawa. According to Dr. Shutt there are two principal reasons for applying lime to soils, viz., to correct or neutralize their acidity or sourness, and to improve their mechanical condition. The influence of lime and its compounds upon the texture of the soils is most beneficial in the case of clays, rendering them less sticky and cohesive, when wet, and more friable and mellow when dry. The excessive use of quick-lime or slaked lime leads inevitably to exhaustion of fertility, and, therefore, they must be carefully applied. Excess of marl, however, can do little or no harm. The application of marl offers no special difficulty; a spreader may be used or the material may be distributed by shovels from a wagon. It may be applied at any season of the year, and it is specially suited to light loams and soils that are poor in organic matter. Like lime, it should be harrowed in, not ploughed under, and in the case of meadows or pastures, merely spread over the surface.

Klotassin Area, Yukon.

INTRODUCTORY STATEMENT.

The greater part of the summer (1916) was spent in Klotassin area, southern Yukon. The area was considered to be favourably situated for the occurrence of various kinds of mineral deposits, and as it was almost entirely unknown geologically, topographically, or even geographically it seemed desirable that it be explored. Further, during the previous summer, placer gold had been found on Rude creek, which drains into Dip creek, a tributary of Klotassin river, with the result that a stampede followed, and not only Rude creek, but a number of other creeks in the neighbourhood were staked, and some prospecting and mining resulted. There followed numerous rumours of important discoveries, but it was not known how authentic these reports were. Possibly the most urgent reason for an investigation of this section of Yukon, however, was the finding of tungsten concentrates on Canadian creek. At the close of the field season of 1915, the writer recognized the presence of wolframite (tungstate of iron and manganese (Fe, Mn) WO_4) in samples of concentrates from placer mining operations on Canadian creek, shown him by a prospector. These samples were

[1] Shutt, Frank T., "Lime in agriculture", Dept. of Agriculture, Dom. Exp. Farms, Ottawa, Bull. No. 80, 1914.

examined in the mineralogical laboratory of the Geological Survey, and found to be very high grade tungsten concentrates. As there has been since the beginning of the war an urgent need for tungsten for use in the manufacture of munitions, this occurrence demanded investigation. Canadian and Rude creeks, also, are not far apart, the mouth of Rude creek being within about 6 miles, measured in an air line, of the point near the head of Canadian creek at which the wolframite has been found to occur most plentifully. It was, therefore, decided to explore and map the area containing Rude and Canadian creeks, and to extend the work in whatever direction seemed most advisable from a mining and geological standpoint. The particular area mapped during the summer, since it is to a great extent drained by Klotassin river, is in this report called Klotassin area.

The drainage and geological features were mapped by running numerous traverses. No attempt was made to make a contoured topographical map. The left bank of Yukon river was traversed from Selkirk down to the now unoccupied telegraph station near Coffee creek. Another main traverse was run from the mouth of Isaac creek on this river traverse, to a point near the mouth of Klotassin river, the geographical position of this point having been previously fairly closely determined. Another traverse was carried from this point to connect with the Coffee Creek telegraph station again. The valley of the Klotassin was traversed from the mouth of the river to near its head; in addition, all the main stream valleys in the area were traversed and numerous cross traverses were run to connect the main lines. These traverses were made in three ways. The main traverses, where possible, were run with plane-table, rod, and stadia; at times, instead, a measuring wheel was used in conjunction with a small plane-table or a Batson sketch board mounted on a tripod; and for the less important, shorter, connecting traverses, pacing was employed in conjunction with a small plane-table or Batson sketch board.

In the performance of this work, the writer, as well as all the members of his party, were assisted in many ways by the different men met within the district, and were assured by all of their entire and hearty co-operation wherever possible. Particular thanks are due G. C. McDonald and E. H. Shafer who during different parts of the summer held the position of government telegraph operator at Isaac creek. They stored the supplies and surplus outfits belonging to the party, looked after the mail, and in many ways rendered valuable and always voluntary assistance. For all courtesies and favours received, the writer wishes to express his sincere thanks.

Throughout the work, the writer was very ably assisted by William E. Cockfield, Clive E. Cairnes, and J. A. McLennan. Mr. Cockfield devoted his time almost exclusively to geological work, and Mr. Cairnes and Mr. McLennan, although assisting with the geology at times, were mostly employed with the topographical work.

LOCATION AND ACCESSIBILITY.

Klotassin area is bounded on the north by Yukon river, and extends along the river from a short distance above the mouth of the Selwyn, to a mile or so below the mouth of Coffee creek, a distance measured along the river of about 35 miles. From Yukon river below Coffee creek, the western boundary extends in a southwesterly direction to Donjek river, a distance of about 30 miles; thence the southern boundary trends in a direction somewhat south of east for between 35 and 40 miles to a point on Klotassin river near its head; and thence the eastern boundary reaches northward to Yukon river again, a distance of between 35 and 40 miles. The area includes over 1,200 square miles.

During the season of open navigation the northern edge of the district is easily accessible from Yukon river, several commodious freight and passenger steamers passing up and down the Yukon between Whitehorse and Dawson each week. Gasoline launches, of a type specially designed and built in Yukon for side-streams work, also can readily run from Yukon river up the White and Donjek to the mouth of the Klotassin. From three points on Yukon river, trails have been built southward into the interior of the area. From near the mouth of Coffee creek, a trail extends up this stream, and thence to Klotassin river, a distance of about 30 miles. This trail, which is known as the Coffee Creek trail, continues thence to Upper White River district.[1] Another trail extends from Yukon river up Britannia creek to the mouth of Canadian creek, and thence continues up Canadian creek for about 5 miles. Above this point on Canadian creek there is a trail for a few miles, but it is very difficult to travel with pack horses. Also several trails have been made from the mouth of Isaac creek over the divide to Rude creek; these follow two main routes, one of which leads to the mouth of Rude creek, and the other to a point near its head, distances from the mouth of Isaac creek of about 16 and 14 miles respectively. A trail extends down Rude creek for about 5 miles to connect the Isaac Creek trails, and continues thence down Dip creek for about 6 miles. These include practically the only trails in Klotassin area, and they are, for the greater part, very difficult to travel, being rough and very soft, since the valleys through which they pass are dominantly wet and floored with muskeg and niggerheads. During the winter, the area is readily accessible with sleighs from Yukon valley.

TOPOGRAPHY.

Klotassin area lies well within that physiographic province known as the Yukon plateau, which extends from about latitude 59 degrees north, in northern British Columbia, through central Yukon and Alaska to Bering sea. This plateau terrane has been described by a number of geologists among whom there appears to be a consensus of opinion that it represents a region which during a long period of crustal stability was extensively planated and reduced to a condition of relatively slight relief. The period of planation was followed by a widespead uplift when the nearly flat or gently undulating lowland became an upland tract. This uplift rejuvenated the streams, giving them renewed head, and increased erosive power, with the result that they commenced immediately to rapidly incise and deepen their channels in the new upland, and to destroy its surface.

In Klotassin area extensive tracts of nearly flat or gently undulating plateau occur separated by intersecting stream valleys; and to an observer stationed on the upland, it is evident that these plateau areas were once all connected to form a single, continuous surface of only slight relief. So situated, and well back from the edges of the valley walls, it is easy for one to imagine the intersecting valleys again refilled, or to forget that they have ever been incised to interrupt the continuity of this plateau surface. The main upland has now a general average elevation of between 4,500 and 4,800 feet above the sea, the mouth of Klotassin river being about 1,900 feet above sea-level. Occasional residual summits rise above the general plateau surface, the highest of which are about 6,300 feet above sea-level. The northern portion of Klotassin area is drained by northward flowing streams including Coffee creek, Excelsior creek, Britannia creek, Isaac creek, Mascot creek, and Selwyn river, which empty directly into

[1] Cairnes, D. D., "Upper White River district, Yukon", Geol. Surv., Can., Mem. 50, 1915, pp. 11, 12.
Cairnes, D. D., "Canadian routes to White River district, Yukon, and to Chisana district, Alaska", Geol. Surv., Can., Map. 113A, 1914.

the Yukon. The remainder of the area is drained by Klotassin river and its tributaries which have a general westerly trend, and empty into Donjek river, a tributary of White river. Between the Klotassin and its tributaries, and those streams emptying directly into the Yukon, there is a long, high, persistent, flat-topped divide which swings in semi-circular form around the headwaters of the Klotassin. One notably long and flat-topped arm of this range lies between Colorado creek and Klotassin river on the south, and Victor and Dip creeks on the north, and extends westerly to near the point where Dip creek joins the Klotassin. Numerous ridges lying between the different streams emptying into the Yukon reach toward this river from the main plateau divide. These smaller ridges are irregular in form, and gradually become lower in elevation as the Yukon is approached, the original upland being there in most places entirely destroyed. To the south of the main divide, the plateau surface is better preserved, but is largely destroyed in the vicinity of the master depressions.

The district shows no evidence of glaciation. The valleys contain interlocking spurs, and the valley walls exhibit none of the rounding, smoothing, and scouring, diagnostic of glaciated areas. The smaller depressions are also decidedly V-shaped, although the master depressions have in places wide floors. The valley walls are prevailingly steeply inclined, being often quite precipitous, indicating a somewhat youthful stage in the physiographic history of the district. Even the valley of Yukon river in this locality is of comparatively recent origin.

In the valley bottoms of the area superficial deposits tend to accumulate somewhat rapidly, due to the fact that the material contributed by the tributaries is largely frozen before it can be carried away by the streams in the valleys, and after becoming frozen its removal is very slow and difficult. On this account, mainly, the valleys of Klotassin river and its main tributaries are gradually being refilled. Overlying the other superficial deposits in the valley bottoms, is nearly everywhere, a layer of soil or muck which is covered with moss, grass, or shrubbery, and is transformed into muskeg and niggerheads, making travelling very laborious.

The main stream in Klotassin area, except the Yukon, is Klotassin river. This stream was not followed quite to its head, but from what is known concerning it, the main valley is thought to be about 60 miles long. Throughout the upper portion of its course, as far as it was explored, the river flows in a general northerly direction, but about 25 miles from its mouth, it makes a sudden turn and below this bend flows in direction almost due west. Several large tributaries join this stream, the most important coming from the right (looking downstream). Three of the largest of these are Dip, Colorado, and Somme creeks. These all hold a general westerly course, Dip creek being about 30 miles long; Colorado and Somme creeks were only explored to points about 12 and 8 miles respectively from the Klotassin, but at these points they were still important streams.

VEGETATION.

The forest growth of Klotassin area is nowhere heavy; trees, however, grow on nearly all the valley floors, as well as in the draws and on the hillsides, up to an average elevation of between 3,500 and 4,000 feet above sea-level. In general, about one-third to one-half of the district is forested, the northern and eastern slopes being better timbered than the southern and western. Only in the valley bottoms, however, and in occasional draws, do trees occur sufficiently large to be used in the construction of buildings or in connexion with mining operations, except as fuel. The largest and best timber in the district occurs or did occur in the valley flats along Yukon river, but much of this has now been cut and used as fuel on the river steamers. In the valley bottoms of Klotassin river, Dip

creek, and Colorado creek there are also many groves in which the trees are tall and stand fairly close together. Altogether, although timber is nowhere very plentiful, there is sufficient that is reasonably accessible to most points to fulfil the ordinary requirements of the miner for a number of years to come. During the past summer, however, much good timber was destroyed by forest fires, which were the result of carelessness and neglect.

The principal forest trees are: white spruce, black spruce, balsam poplar, aspen poplar, and northern canoe birch. There are also a number of shrubs some of which in places attain the dimensions of trees; these embrace several species of willow, one or more of alder, and dwarf birch.

The white spruce is the largest, and much the most useful and important tree, and as well, is the most plentifully distributed of the larger forest members. It grows at all elevations up to timber-line, but favours dry slopes and well-drained portions of the valley bottoms. The best groves generally occur in the valley flats and in depressions along the lower slopes of the ridges and in such locations the trees are straight and well grown. The trunks are generally not more than 12 to 18 inches in diameter 3 feet from the ground, but groves occur in which specimens with 24-inch stumps are fairly plentiful. This tree furnishes strong easily worked timber, and is well suited to the usual needs of the miner, and for purposes of construction generally. Black spruce occurs associated with the white spruce mainly in peat bogs or other poorly drained portions of the valley bottoms, and on the lower hillsides, particularly those facing the north, but it is not as large or well grown as the white spruce. Aspen poplar and balsam poplar constitute a large portion of the forest growth both in the valleys and on the hillsides. Balsam poplar grows best along the alluvial flats of the main valleys, while aspen extends higher up on the drier hillsides. Specimens were seen in all stages of growth from small shrubs to trees 10 to 14 inches in diameter or even larger. The poplars make good fuel if the wood is properly cured, but they are too soft and generally too irregular in form to be of any use for constructional purposes. The northern canoe birch, which is nowhere very plentiful, is seldom more than 8 to 10-inches at the stump, and is of value mainly as fuel. Willows, alders, and dwarf birch constitute the greater part of the shrub growth of the district. The willows are plentiful in the valleys, but do not in most places extend far above the level of the larger streams. The dwarf birch occurs chiefly in the higher valleys, and along the upper slopes near timber-line, and in places extends well over the upland. The alder occurs associated with the willows and birch, extending well above the tree-line to practically the shrub limit, and in places along the mountain slopes it is found practically unassociated with other varieties of shrubbery.

The valley bottoms of Klotassin river, Dip creek, and Colorado creek, as well as of some of their larger tributaries, are in places quite open and are covered with luxuriant growths of grasses which would constitute good fodder for horses or cattle. Some of the best meadow lands occur in Klotassin valley for 10 miles above the mouth of Dip creek; also in the valley of Dip creek between the mouths of Rude and Victor creeks; and in Klotassin valley below the mouth of Dip creek. The flats of these valleys range in width from ½ to 3 or 4 miles, and constitute important extents of meadow or pasture lands.

A small collection was made of the flowering plants of the district. This was given to James Macoun, botanist of the Geological Survey, for examination. He states: "The specimens are of the best and altogether the collection is very interesting. The *Cardamine* may be an undescribed species. We have had nothing like it before and I can find no description that covers it in Flora Rossica, which includes all the Siberian plants. The *Arabis* is also an addition I think. The *Phacelia* is the same as one collected near Dawson some years

ago by a man named Williams and published simply as *Phacelia* n. sp." The following is the list as furnished by Mr. Macoun:

Salix rostrata Richards.
Polygonum plumosum Small.
Silene acaulis L.
Lychnis? Specimen too young.
Cerastium nutans Raf.
Stellaria longipes Goldie.
Papaver radicatum Rottb.
Aconitum delphinifolium DC.
Corydalis sempervirens (L.) Pers.
" *pauciflora* Pers.
Arabis.
Cardamine.
Parrya macrocarpa R. Br.
Dryas octopetala L.
Parnassia Kotzebuei Cham. and Schlecht.
Chrysosplenium tetandrum Fries.
Dodecatheon frigidum C. and S.
Polemonium pulchellum Bunge.
" *caeruleum* L.
Phacelia.
Myosotis sylvatica Hoffm.
Pedicularis capitata Adams.
" *scopulorum* Gray.
Lagotus glauca Gärtn.
Arnica alpina Olin.
" *latifolia* Bong.
Senecio frigidus Less.

Mr. Macoun later writes: "I had a letter from Dr. Rydberg of New York to whom I sent the three species I had taken to be new to Canada. He has the following to say about them:

'90,004. Cannot determine from the specimen. It probably is not an *Arabis*, at least we have no specimens like it. It seems more closely related to *Pilosella* (*Stenophragma, Arabidopsia*) *Richardsoniana* Rydb., which was included by Dr. Robinson in *Braya humilis*, but that species is a perennial and your plant looks like an annual. The pubescence is of that genus and so is the stigma. The two-lobed stigma would exclude it from *Arabis*, as far as I know.

90,003 *Cardamine Blaisdellii* Eastw.

90,006 *Phacelia* sp. This is closely related to *P. sericea*, but the pubescence is different and the corolla is larger and white instead of bluish purple. We have nothing like it in our collections.'

"They are as I thought all additions to our known flora, and two of them seem to be undescribed species. In looking up the literature I find that the *Cardamine* was described by Miss Eastwood from a small collection made near Nome. The *Phacelia* I will describe myself, but the *Crucifer*, No. 90,004, is so immature that Rydberg, as well as myself, is doubtful about the genus."

GAME.

Big game abounds in Klotassin area, moose and bear being particularly numerous and sheep and caribou also inhabit parts of the district. The moose are the large giant moose; these magnificent animals are to be seen almost anywhere throughout the area, but range mainly in the lowlands, and are particularly plentiful in the valley flats of Klotassin river, Dip creek, Victor creek, and Colorado creek. The bear are mainly a very large brown variety, and are exceedingly numerous, particularly within the portion of the area drained by Klotassin river. The caribou are mainly, at least, the large woodland variety,

and are fairly plentiful on the low open hills in parts of the district. The sheep are the white Alaskan variety; they feed during the winter months in the main valleys, but with the approach of summer, work farther and farther back into the higher mountains and choose especially the lofty, rugged, craggy summits.

Rabbits which were very plentiful in southern Yukon until a year or so ago, are now very scarce, and in Klotassin area very few were seen last summer. The chief fur-bearing animals in the district are lynx, mink, marten, wolverine, and red fox which are fairly numerous in places; cross, silver, and black foxes also are occasionally found.

The chief game birds are rock ptarmigan, willow ptarmigan, Alaska spruce partridge, fool hens or Franklin grouse, sharptailed grouse, geese, and various varieties of ducks. The ptarmigan are reported to have been very plentiful until the past two summers, but now they as well as the grouse are very scarce. Ducks are fairly plentiful on some of the lakes in the valley flats.

The streams and small lakes are generally well stocked with fish, chiefly grayling. In Yukon river other varieties of fish also occur, including mainly salmon and pike.

GENERAL GEOLOGY.

General Statement.

The geological formations exposed within Klotassin area range in age from probably Pre-Cambrian, to Recent, and include both sedimentary and igneous members. Some metamorphic rocks of somewhat obscure origin also are present. The most extensively developed terrane of consolidated rocks is a granitic-batholith, probably of Cretaceous or Jurassic age, which reaches completely across the area, and extends an unknown distance beyond in both directions. The next most important geological formation is composed entirely of metamorphic rocks, probably all of Pre-Cambrian age. These rocks embrace members of both sedimentary and igneous origin. They are characteristically schistose and gneissoid in character, but include some beds of massive crystalline limestone. The other consolidated geological formations of Klotassin area, are dominantly volcanic rocks ranging in age from early Mesozoic to, probably, fairly late Tertiary; they are for the greater part, semi-basic to basic in character, and include chiefly andesitic and basaltic members.

Table of Formations.

Era	Period	Formation		Lithological Character
Quaternary	Recent and Pleistocene	Superficial deposits		Gravel, sand, clay, silt, soil, muck, ground-ice.
Tertiary				Rhyolite, granite porphyry, and related volcanics.
		Correspond for the greater part at least, to the Newer Volcanics of Upper White River district.		Mainly andesite, basalt, and related volcanics; in places dominantly tuffaceous, the tuffs passing gradually into pure sandstones and conglomerates.
Mesozoic (may include some late Palæozoic members)	Probably Cretaceous or Jurassic.	Probably correspond to Coast Range intrusives		Granitic rocks ranging in composition from granite to diorite, with associated porphyritic phases.
	Probably mainly about Jurassic, but may include older members	Older Volcanics of Upper White district.		Andesite, diabase, basalt, and related volcanics, with associated tuffs and breccias.
Pre-Cambrian(?)		Yukon Group	Pelly gneisses	Granite gneiss.
		Yukon Group		Dominantly hornblende schist and gneiss, include also some sericitic gneiss and schist. Igneous origin.
		Yukon Group	Appears to correspond to Nasina series.	Mica schist, mica gneiss, quartz-mica schist, quartz-mica gneiss, schistose and gneissoid quartzite, sheared conglomerate, phyllite, and limestone. Sedimentary origin.

Summary Descriptions of Formations.

The oldest rocks exposed in Klotassin area are dominantly schistose or gneissoid in character and belong to the Yukon group which is thought to be entirely of Pre-Cambrian age.[1] These rocks are extensively developed in Klotassin area, and it was possible in the field to classify them into three main divisions. The most recent of these divisions is composed entirely of rocks that will here be termed granite gneisses, as they are evidently altered granitic rocks. The other members fall into two groups, one of igneous and the other of sedimentary origin. The members of the sedimentary division are the oldest rocks in the district, and appear to correspond to McConnell's Nasina series.[2] They consist dominantly of mica schists and gneisses, quartz-mica schists and gneisses, schistose and gneissoid quartzites, phyllites, and bands of crystalline limestone. There is every transition from a rock composed almost entirely of quartz, to a definite mica schist. In places the mica or quartz-mica schists and gneisses are highly garnetiferous, the garnets being as much as one-quarter inch in diameter;

[1] Cairnes, D. D. "The Yukon-Alaska International Boundary," Geol. Surv., Can., Mem. 67. 1914, pp. 38–44.
[2] McConnell, R. G., "Report on the Klondike gold fields", Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 12B–15B.

in other places they exhibit considerable tourmaline which occurs in crystals as much as 1½ inches in length. The older igneous division of the Yukon group is, dominantly at least, more recent than the sedimentary rocks, and includes mainly hornblende schists and gneisses, but some light grey to nearly white sericitic schists and gneisses also occur. All these sedimentary and igneous rocks, in addition to being intensely metamorphosed, are greatly distorted, folded, broken, and often even crumpled. The granite gneisses have the general appearance of dominantly coarsely textured, laminated granites, and distinctly cut the other members of the Yukon group. They evidently correspond to the Pelly gneisses which have been described by a number of writers.[1]

More recent than the members of the Yukon group is a group of rocks corresponding to the Older Volcanics[2] of Upper White River district. These have only a relatively small development in Klotassin area, and are exposed mainly along the lower portion of the valley of Klotassin river. They are prevailingly dark coloured, greyish to greenish rocks, and include mainly andesites, basalts, and related types with their tuffaceous phases. These rocks are for the greater part quite massive, but in places they have a decidedly laminated structure. They are also in places much altered to epidote, and in places, for several hundred feet, are almost entirely changed to serpentine. Also they locally contain notable amounts of dolomite; and especially along Yukon river for a few miles below Selkirk, veins and irregular masses of this mineral nearly everywhere characterize these rocks. They are probably of early Mesozoic age, but may include older members.

The most extensively developed geological terrane in Klotassin area consists of granitic rocks ranging in composition from granite to diorite, with associated porphyritic phases. These rocks comprise a batholith which was explored for a length of about 50 miles, but neither end was reached. The width where mapped is in most places from 15 to 20 miles. This batholith much resembles the northern portion of the main Coast Range batholith, and may really be an outlying, subjacent portion of it. These granitic rocks cut the Older Volcanics and are probably of Jurassic or Cretaceous age.

Cutting the granitic intrusives there is developed a group of rocks corresponding apparently to the Newer Volcanics[3] of Upper White River district. These rocks include mainly andesitic and basaltic volcanics, and are everywhere massive and fresh appearing, and are prevailingly very susceptible to weathering agencies. In places they are so generally decomposed that it is very difficult to obtain a firm, solid, hand specimen. This group of rocks also includes a considerable proportion of pyroclastics, and the tuffs in places grade into true sediments. At one point beds of ordinary appearing shales, sandstones, and conglomerates are included with the tuffaceous members, and are intimately associated with them. These rocks are believed to be of Tertiary, probably early Tertiary, age.

More recent than all these older rocks, there occur, in places, dykes of rhyolite, granite porphyry, and related volcanics. These have no particular areal importance and appear to be genetically related to the granitic intrusives. Possibly they are a later phase of the same magma.

Overlying all the consolidated rock formations of the district, are the Pleistocene and Recent accumulations which include mainly gravel, sand, clay, silt, soil, muck, and ground-ice. These not only cover deeply all the main valley bottoms, but in addition, extend over considerable portions of the valley walls and upland.

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[1] McConnell, R. G., "Note on the so-called basal granite of Yukon valley", Am. Geologist, vol. XXX, July, 1902 pp. 55–62.
[2] Cairnes, D. D., "Upper White River district, Yukon", Geol. Surv., Can., Mem. 50, 1915, pp. 87–93.
[3] Cairnes, D. D., "Upper White River district, Yukon", Geol. Surv., Can., Mem. 50, 1915, pp. 97–101.

MINERAL RESOURCES.

General Statement.

The only minerals that are known to have been so far discovered in Klotassin area, in deposits of economic importance, are gold and wolframite (tungstate of iron and manganese (Fe, Mn)WO_4), both of which have been found only in placer form. For a number of years there has been a small gold production from Canadian creek, and last season a few hundred pounds of wolframite was also recovered there. Between 1911 and 1914, some prospecting and a small amount of mining were done on Britannia creek. Coffee creek has also been prospected to some extent. In addition, some of the tributaries of Selwyn river have been prospected, and for several years there has been a small annual output of gold from points on one of the tributaries of this stream a short distance east of the area mapped last summer. This includes practically all that was done in the way of mining or even of prospecting in Klotassin area and its immediate vicinity, until the spring of 1915 when gold was discovered on Rude creek. This discovery caused a stampede which resulted in the staking of all of Rude creek, as well as part of its parent stream, Dip creek, and several of their tributaries and sub-tributaries, including Trombley, Ray, Jens, Odin, Northey, Brown, Casino, Victor, Woodburn, and Bird creeks. Isaac creek and several of its tributaries, including Sunshine, Moonshine, Teddy, Idaho, and Alder creeks were also staked. A certain amount of prospecting has been done mainly on Rude creek and its tributaries, as well as along the upper portion of Dip creek, and on Isaac and Sunshine creeks. Actual mining has been done, however, only on Rude creek, and the production has been very small. It is expected that considerable prospecting will be performed this winter on the lower portion of Rude, and on Dip and Isaac creeks, as well as possibly in other places where the ground is sufficiently deep to be adapted to drifting.

Canadian Creek.

Canadian creek is a tributary of Britannia creek, and joins it from the southwest about 5 miles above its mouth; Britannia creek joins the Yukon from the south about 50 miles below Selkirk. Discovery on Canadian creek is about 2 miles above its mouth, and was staked on April 21, 1911, by Jos. Britton and Chas. J. Brown. During the past summer only three claims, having a total length of about 1,500 feet, were being held on Canadian creek; these are located near the upper end of the creek, and are recorded as Nos. 71, 72, and 73 above Discovery. This ground was owned, when visited, by Daniel Mann, Nicola Hansen, and P. S. Larsen. Since then, it is understood, Larsen has sold his interest. Between the spring of 1911, and 1913, some prospecting was done at several points along the lower portion of Canadian creek, and from what can be learned as a result of this, it would appear that much of the ground might be mined at a profit, if the work were done to advantage. The indications are that this portion of the creek below the canyon is quite adapted to dredging. In the spring of 1913, Messrs. Mann, Hansen, and Larsen, moved to the upper portion of the creek, and have since then, each summer, mined the ground they now hold. From 1913 until the present, very little other work has been done on Canadian creek.

A small tributary stream about one-quarter mile long, joins Canadian creek on its right limit near its head, and about 8 miles above Britannia creek or 13 miles from the Yukon, measured along the valley bottom; and it is near the mouth of this small tributary, and well above timber-line, about 2,700 feet in elevation

above the mouth of Britannia creek, that Mann and partners have performed most of their work. The depth to the bedrock channel along this upper part of Canadian creek is not known. Several shafts have been sunk, the deepest of which is 42 feet, but in only one of these was bedrock encountered, and there it was a sloping rim. The uppermost deposit at the workings of Mann and partners is a layer of muck about 3 feet thick, and directly underneath this are the pay gravels which have a thickness of 3 to 5 feet. Below these gravels, the various deposits down to bedrock, so far as they have been explored, do not pay to mine. These deposits in places are cemented by a reddish, iron-stained matrix, to form a "hard-pan" or really quite a firm conglomeratic rock. The open-cut comprising the workings of Mann and partners is 75 feet wide, and is all in paying ground; thus the width of the pay gravels here is known to exceed 75 feet. In all, these partners have taken out between \$6,000 and \$7,000 in gold since the spring of 1913, of which between \$1,500 and \$2,000 was obtained during the past summer. They, however, did not commence to save the wolframite until last season, when only two of them were engaged in actual mining operations much of the time, the third being in ill health. Nevertheless, in a very short season, they recovered, in addition to the gold, between 500 and 600 pounds of high grade wolframite concentrate. Part of this has been shipped to the Canadian Munition Resources Commission, Ottawa, and was tested in the Ore Testing plant of the Department of Mines, and found to contain 64·42 per cent WO_3.

The mountains surrounding the head of Canadian creek are dominantly composed of Mesozoic granitic rocks. The small tributary stream near the mouth of which Messrs. Mann and partners are working, however, heads in a round hill about a mile in diameter, which is composed largely of pegmatitic and porphyritic rocks. The pegmatitic rocks are an extreme phase of the granitic terrane, while the porrphyry, although possibly genetically related to the granitic intrusives is more recent, and has extensively invaded them. The whole pegmatite-porphyry hill is highly mineralized, chiefly with a yellowish iron ochre which is largely the decomposition product of iron-containing minerals, including pyrite, magnetite, and hematite. Some pyrite, magnetite, and hematite are still in evidence, but near the surface, they are for the greater part leached out leaving the iron ochre filling the various cavities which they formerly occupied. The central portion of this hill for a width of perhaps 1,500 feet is composed of a particularly quartzose pegmatitic rock, the quartz being associated mainly with hornblende, feldspars, and related minerals. This pegmatite is intersected in all directions by ramifying veins and stringers of quartz, so that the entire central mass of the hill is largely composed of quartz. It is evidently from this hill that the gold and wolframite now found in the gravels a few hundred feet below has been derived, although no single specimen could be found on the surface in which wolframite could be detected. Furthermore, three chipped samples A, B, and C were taken across about 900 feet of the central, best mineralized portion of this hill, each sample covering about one-third of the distance. These were assayed by the Mines Branch, Department of Mines, Ottawa, and were found to contain only slight amounts of gold and WO_3 (tungsten trioxide) as follows:

Sample	WO_3	Gold per ton.
A	Trace	40 cents
B	0·10 per cent	Trace
C	0·10 per cent	Trace

However, there is no evidence of glaciation in this vicinity, and, therefore, the gravels are all of local origin. Furthermore, the gold and wolframite occur dominantly at least in gravels near the surface, and the gold is notably very rough, the larger pieces including considerable quartz, and resembling fragments of

rich gold-quartz veins rather than ordinary nuggets indicating that the gold has been only slightly transported. It thus seems quite evident that the gold and wolframite were derived from this pegmatite-porphyry hill in which heads the small stream whose gravels are being mined only a few hundred feet below. Apparently a portion of this hill richer, in wolframite at least, than that part now exposed, has been broken down by stream and weathering processes to form the present placer deposits. As a result of the prospecting to date the wolframite appears to be practically limited in its occurrence to a portion of the basin at the head of Canadian creek, and is most plentiful in the vicinity of the present operations. Only a relatively small amount of this mineral has been carried any considerable distance downstream by Canadian creek. Gold prospects are believed, however, to have been found at a number of points along this upper portion of Canadian creek.

Next summer (1917), if the present plans of the owners are carried out, a production of 600 to 1,000 pounds of wolframite concentrates similar to that recovered during the past summer is to be expected, and also an amount of gold comparable to that obtained in the past season. If more men are employed and more equipment is installed, a greater production could be obtained, but owing to scarcity of water, the wolframite production at least probably could not be profitably increased to any very great extent. Thus in the ordinary course of events a production approximating only to that of last summer is to be expected for a number of years to come.

A fairly good trail continues up Britannia and Canadian creeks for 10 or 11 miles from Yukon river. Above this to the workings of Mann and partners, the trail is very difficult in summer, being practically impossible for pack horses, particularly for a distance of about 2 miles through a constricted portion of the valley, locally known as the canyon, and for some distance above it, due to the occurrence of large granitic talus blocks which are strewn completely across the valley. In winter there would be no difficulty in sledding concentrates down Canadian and Britannia creeks to the Yukon, and in the spring these can be shipped on the river steamers which ply regularly up and down the Yukon all summer, and connect with outside points.

Rude Creek.

Rude creek is a small stream whose main valley is about 6 miles long; it empties into Dip creek from the left (looking downstream), near its head, Dip creek above the confluence of these streams being comparable in size to Rude creek. The easiest way to reach Rude creek is by trail from the mouth of Isaac creek. Isaac creek joins Yukon river from the south about 43 miles below Selkirk. Two main trails have been constructed to Rude creek, and reach it near the head and near the mouth respectively, and at distances from the mouth of Isaac creek, of respectively about 14 and 16 miles.

The valley of Rude creek is decidedly V-shaped in cross-section, with walls rising rather abruptly to a height varying from a few hundred to over 1,000 feet, to meet the general upland. The hillsides constituting these valley walls, except near the extreme head of the creek, are nearly everywhere forested, mainly with small spruce; some poplars and shrubbery, however, also occur. Even the valley flat, which is in most places from 500 to 700 feet in width, is covered with a sparse growth of trees and shrubbery. The stream has no open flood-plain, but instead follows a narrow channel incised through the moss, muck, and underlying gravels.

The hills at the head of Rude creek, and down both sides of it, are composed entirely of granitic and porphyritic rocks. The granitic rocks are the Mesozoic

intrusives which in places are porphyritic; these are cut by numerous dykes mainly of granite porphyry and rhyolite. Thus, since this vicinity has not been glaciated, the stream gravels are all of local origin, and consist almost entirely of these granitic and porphyritic rocks.

Discovery claim which is about 3 miles from the mouth of the creek, was staked on March 12, 1915, by Jens Rude and George Jensen, who worked on Rude creek a great part of the summers of 1915 and 1916. Bedrock along the upper part of the creek to below Discovery and in the central part of the valley is from 2 to 10 feet deep, in most places from 6 to 10 feet. At about No. 2 below Discovery, bedrock commences to get much deeper, but just how deep it is along the lower part of the creek has not been determined. Small deposits of terrace gravels occur in places along the valley walls, a few feet above the present valley bottom, and indicate positions Rude creek formerly held during the process of sinking its channel to its present level. When visited in June, about twenty-five men were engaged in prospecting and mining along Rude creek, but later in the season many of them left. It is expected, however, that a number of those owning claims with deep bedrock, will prospect their ground, by drifting, this winter. It is estimated that about $800 in gold was obtained from Discovery claim during the autumn of 1915, and during 1916, the owners claimed, while mining, to be recovering gold amounting to about wages, or a little better. In all probability less than $2,000 in gold has been obtained from Rude creek, nearly all of which came from Discovery. As a result of the work so far performed on this creek, the distribution of the gold both in the creek and terrace gravels, appears to be not only sparse, but very erratic.

Other Creeks.

Some prospecting has been done on Isaac creek, and some of its tributaries, with, it is claimed, promising results. Also some work has been done on Dip and Victor creeks, and some of their tributaries, as well as on the tributaries of Rude creek, but the results are indefinite. Britannia creek on which Discovery was staked on April 18, 1911, by E. L. C. de la Pole and C. M. Printz, was prospected to quite an extent during 1911 and 1912, but no work has been done there since 1914. It is claimed that the results of the work there performed, indicate that the portion of the creek below the mouth of Canadian creek, about 5 miles in length, would pay well for dredging. The physical conditions, amount of water, etc., are, at least, adapted to dredging, and the bedrock in most places along the central part of the valley is only from 18 to 20 feet deep. It is thus hoped that this lower part of Britannia creek may be profitably dredged in the near future. Casino creek has been very slightly prospected, but one branch of this stream heads in the same pegmatite-porphyry hill as the small tributary of Canadian creek on which Mann and partners are working, and there also the same reddish gravels were noted. It is quite possible, therefore, that gold and wolframite may occur there the same as on Canadian creek, or even in greater amounts. Timber for fuel and constructional purposes is much more accessible than at the head of Canadian creek, so the working costs would be no more, and might prove somewhat less.

SUMMARY AND CONCLUSIONS.

Klotassin area, as a whole, has been only slightly investigated and explored, and practically the only prospecting that has been done, has been for placer gold. Even in the case of placer gold, with the exception of Britannia and Canadian creeks, the prospecting has been largely confined to Rude creek and

its close proximity. All around Rude creek, the geological formations are of Mesozoic or more recent age, and consist dominantly of granitic rocks which are extensively invaded by granite porphyry, rhyolites, and associated rocks. Such comparatively recent rocks, dominantly granitic, have not in Yukon or Alaska been so far found to give rise to placer deposits of any considerable importance. In the more southerly and southeasterly portions of Klotassin area, the geological formations consist largely of old, probably Pre-Cambrian metamorphic rocks which are to a great extent of sedimentary origin. These are extensively invaded by granitic, andesitic, basaltic, and other intrusives. Such a combination of geological formations is very favourable for the production of placer gold deposits, especially since there, as elsewhere in Klotassin area, no glaciation has taken place, and wherever valuable placer deposits have accumulated, there they probably still remain. It is particularly advisable, therefore, that the creeks of that portion of the area be carefully prospected, the smaller creeks being first tested, where the physical conditions are favourable, and where quick results can be obtained.

Scheelite and wolframite are reported to have been found in several portions of Klotassin area, but, so far, Canadian creek is the only locality where any tungsten mineral is actually known to have been discovered. The geological conditions are favourable for the occurrence of tungsten minerals throughout the granitic area, and especially around its periphery.

Saline Incrustations between Takhini and Canyon, Y.T.

Saline incrustations occur at a number of points throughout the wide valley occupied by Dezadeash river, and are particularly conspicuous along the Whitehorse-Kluane wagon-road from mile-post 30 to mile-post 85 between Takhini and Canyon roadhouses. This saline material is white or nearly white in colour, and occurs mainly around the edges of many of the small lakes, ponds, or sloughs in the valley bottom, being left as a residue after the evaporation of the water. Along the wagon road, this material is most plentiful near 32 mile-post, near 40 mile-post, near Champagne Landing, and in the vicinity of Big Bend. Near 32 mile-post or in the vicinity of the point where the Whitehorse-Kluane road branches off the main Whitehorse-Dawson road, the saline material occurs around a number of ponds or sloughs, but is only a surface blossom with practically no thickness. The deposits near 40 mile-post, and in the vicinity of Champagne Landing, are of the same character, as are also others at various points between Champagne Landing and Big Bend, and for about 2 miles past Big Bend. The purest and most extensive deposits that were seen, occur just east of Big Bend which is about 13 miles west of Champagne Landing. There, for a distance of about one mile, a wide, nearly dry slough occurred, when visited, and the surface of the ground was covered with this whitish material, and, in places, quite pure white to colourless crystalline salts occurred in a layer $\frac{1}{8}$ to $\frac{1}{4}$ inch thick.

A typical sample of this saline incrustation was collected by the writer from a point near Champagne Landing in 1914. This was examined in the laboratory of the Mines Branch of the Department of Mines, Ottawa, and reported upon as follows:

> "It proved on examination to be composed for the most part of a mixture of hydrated sulphates of sodium and calcium, and a small quantity of magnesium sulphate, with some insoluble argillaceous and organic matters. It is slightly ferruginous, and contains also a very small quantity of phosphates and chlorides."

It was thought this saline material might possibly contain important quantities of potash which is now greatly in demand; accordingly the writer was in-

structed to sample the various incrustations during the past summer. This was done early in August and twenty-three samples were taken. Six of these were tested for potash in the chemical laboratory of the Mines Branch of the Department of Mines, Ottawa, and found to contain potash as follows:

Sample No.	
No. 1	0·2 per cent K_2O
No. 5	0·3 "
No. 10	0·2 "
No. 14	0·2 "
No. 18	0·2 "
No. 23	0·2 "

It was thus decided that it would not be advisable to go to the expense of testing the remaining samples since those examined were found to contain potash in such slight amounts. This saline material would thus appear to be of no present economic value.

Lode Mining in the Windy Arm Portion, Conrad Mining District, Southern Yukon.

INTRODUCTORY STATEMENT.

During 1904 and 1905, a considerable number of mining claims were located in what is generally known as Windy Arm district, southern Yukon, most of which were acquired by Col. J. H. Conrad and the organizations which he controlled. In the spring of 1905 Col. Conrad commenced to develop these claims on quite an extensive scale, and continued operations until the summer of 1912 when he was obliged to close down, and the properties were taken over for money previously advanced, by the Mackenzie and Mann interests. From that time until the past summer (1916), no work was done on these properties. A number of additional claims constituting what has been generally known as the Dail and Fleming group, as well as the Ruby Silver, and possibly a few others, which were located about 1904 or 1905, are also still held, and on them a certain amount of development has also been done which, especially of late years, has been mainly in the form of the yearly representation work required by the government on all mining properties that are not crown granted.

Last spring (1916) the Lakinaw and Tagish Mines of Seattle, also known as the Harper syndicate, obtained a lease and bond on a number of the Conrad properties including the Montana, Mountain Hero, Vault, Venus No. 1, Venus No. 2, M and M, Joe Petty, Uranus No. 1, Uranus No. 2, Little Johnnie, Capella, and Black Jack. Mr. J. L. Harper of Seattle is general manager of this syndicate, and Mr. J. E. McFarland is superintendent of operations in southern Yukon. This syndicate commenced operations early in June, continued all summer, and proposed mining throughout the winter. The bulk of the work was done on the Venus No. 2 from which some small shipments of ore were made. Work was also commenced on the M and M and on the Montana.

Col. W. L. Stevenson, on behalf of the Alaska Corporation of Skagway, Alaska, or some of its subsidiary organizations, obtained from Mackenzie and Mann a working lease on the Big Thing and also commenced work last June (1916). Operations were continued all summer and it is expected that mining will be carried on throughout the winter.

Thus, as there has been practically no mining done in Windy Arm district since 1912, except a limited amount of yearly representation work on a few

claims adjoining or near the Conrad properties, the commencement of operations again during the past summer has done much to encourage the lode mining industry of southern Yukon, and is regarded as a favourable omen for the near future. Accordingly, after completing work on Dublin gulch, and in Klotassin area, the writer spent a few days during the early part of October in Windy Arm district, and visited the properties there being developed. Both R. G. McConnell and the writer had examined the various Windy Arm mining properties during the early stage of their development, and have published brief reports[1] concerning them. Thus in this report which is to be regarded as merely of a preliminary nature, only those properties will be described on which work has recently been done. These include the Big Thing, Venus, M and M, and Montana, as well as certain claims of the Dail and Fleming group. Very little work has been done on any of the other properties of the district since the writer's early reports were published. The ore deposits on all these properties are fissure veins which, with the exception of the Big Thing, intersect andesitic rocks; the Big Thing vein occurs in granitic rocks.

The information in this report concerning the values contained in the different veins has been derived from a number of sources. Since 1905, when mining operations were commenced in Windy Arm district, the writer has kept closely in touch with the development of the various porperties, and has had access, through the courtesy of the owners, to all assay returns of samples taken from the different properties. Also these properties have been practically all carefully sampled at times for prospective purchasers, and in some cases the results of the assays of these samples have become known to the writer; and occasionally when reports were made by well known, and competent engineers, these reports have been afterwards loaned to the writer. In addition, much valuable information has been obtained from the government assay office in Whitehorse, where hundreds of samples of Windy Arm ores have been tested. Furthermore, in 1912, Mr. T. A. MacLean sampled a number of the Windy Arm properties for the Mines Branch of the Department of Mines, Ottawa, and the results of his work have been published.[2]

LOCATION AND ACCESSIBILITY.

The area that is in a general way known as Windy Arm district lies for the greater part at least in the southern portion of Conrad mining district of southern Yukon; but, as the upper end of Windy Arm reaches south of the 60th parallel, the Yukon-British Columbia boundary, Windy Arm district, might be considered to extend into northern British Columbia. The properties described in this report, however, are all in Yukon, and all lie within an area bounded on the south by the 60th parallel, on the west by lake Bennett, on the north by Nares lake and Tagish lake, and on the east by Windy arm, and are thus included between longitudes 134° 40′ and 134° 50′ and between latitudes 60° 00′ and 60° 10′.

Caribou[3], a point on the White Pass and Yukon railway, serves as a distributing centre for Windy Arm district. This point is 68 miles by rail from Skagway which is itself situated at the head of Lynn canal. From Skagway, coast steamers make regular and frequent trips to Vancouver and Seattle, distances respectively of 867 and 1,000 miles. From Caribou a wagon road has been built to the Big Thing, a distance of about 6 miles. Another wagon road has been built from Caribou to Conrad, a deserted village on the west shore of

[1] McConnell, R. G., "Windy Arm district", Geol. Surv., Can., Sum. Rept., 1905, pp. 26–32.
Cairnes, D. D., "A portion of Conrad and Whitehorse mining districts, Yukon", Geol. Surv., Can., 1908.
"Windy arm", Geol. Surv., Can., Sum. Rept., 1907, pp. 13, 14.
"Windy arm", Geol. Surv., Can., Sum. Rept., 1908, p. 31.
[2] MacLean, T. A., "Lode mining in Yukon", Dept. of Mines, Mines Branch, 1914, pp. 188–201.
[3] The name of the post-office at Caribou station is Carcross.

Windy Arm. The distances from Caribou to Conrad and the Venus mine, by water, are 11½ and 15½ miles, respectively; and practically all freight to and from points along Windy Arm at present, goes by water. There is a good grade for a railway from Caribou along the shores of Nares lake, Tagish lake, and Windy Arm, whenever it is found advisable to build such a road. Thus the Windy Arm properties are all quite readily accessible, and practically all except the Big Thing, are situated at distances of from ½ to 4 miles from Windy Arm, and at elevations of from 1,200 to 3,600 feet above it. Thus all ore to be conveyed to the water's edge for shipment or treatment, has a downhill haul, for which aerial tramways have been or can readily be constructed.

BIG THING.

General Statement. The Big Thing is located about 5½ miles almost due south from Caribou whence a good wagon road has been built to the property. It is also situated above timber-line, and near the summit of a gently contoured hill known as Sugar Loaf hill. The upper workings on the property have an elevation of about 3,500 feet above lake Bennett which is about 2,160 feet above sea-level.

The Big Thing was owned for a number of years by one of the Col. Conrad organizations which did the initial development on the property in 1905. In 1912 the Big Thing was taken over for money advanced, by representatives of Mackenzie and Mann who still own the property. Last June Col. W. L. Stevenson, managing director of the Alaska Corporation of Skagway, Alaska, commenced to re-open the property on behalf of the Alaska Corporation or one of its subsidiary organizations, he, it is understood, having obtained a working lease from Mackenzie and Mann.

Development. Development work on the Big Thing began in 1905, and continued for the greater part of the time from then until June, 1912. During July and August, 1912, some contract work was also performed. From that time, however, the property was not again worked until June, 1916.

During the years 1905 to 1912 a considerable amount of work was done on this property, much of which, however, is now of little or no value. An incline shaft was sunk 450 feet, which follows the vein down from the surface for about 400 feet; in this distance one or two faults of slight displacement were encountered. At a depth of 400 feet, measured down the incline shaft, another fault was struck, but the shaft was nevertheless continued for 50 feet or more at practically the same inclination, although the vein did not again appear. Four levels were driven from the shaft, but the vein has been most developed on the third and fourth. The first level comprises about 120 feet of drifting, the second, about 50 feet, the third or 300-foot level, about 185 feet, and the fourth or 400-foot level, over 700 feet of drifting. Some stoping was also done, two winzes having an aggregate depth of 40 feet were sunk, and various irregular workings were excavated.

An adit or so-called tunnel, intended to crosscut the vein at depth, was driven 2,320 feet, and from this adit, several irregular prospecting crosscuts as well as two long, irregular upraises were driven. One of the upraises was considerably misdirected, and did not encounter the vein at all. The other, driven from near the end of the adit, finally tapped the vein at the 400-foot level in the upper workings, and near the point where the shaft crosses this level. In the adit, a vein about 18 or 20 inches in thickness is crosscut, which has a strike and dip similar to the main vein above, but it is not at all certain they are the same vein.

During the past summer most of the old workings were again opened up, and the vein was further developed on and immediately below the 400-foot level. A branch upraise was also driven off one of the upraises from the adit; this branch upraise was started from near the top of the old upraise to the 400-foot level, and in it the vein was again encountered, this time a few feet below this level.

Vein. The ore deposit on the Big Thing is a fissure vein which intersects granitic rocks of Jurassic or Cretaceous age. It strikes approximately north 55 degrees east (astronomic),[1] and dips to the northwest at angles generally between 25 degrees and 35 degrees. It is usually from 2 to 8 feet in thickness, although in places it is as much as 12 feet thick; and it is composed dominantly of quartz which is fairly well mineralized chiefly with pyrite, but also contains some disseminated arsenopyrite, as well as occasional particles of chalcopyrite, galena, and stibnite. The vein is chiefly of value for its gold content, but also contains some silver.

To the east of the shaft, the formation is in places much disturbed and broken; and great difficulty has been experienced in following the vein there, due to its being repeatedly faulted in various directions. To the west of the shaft, however, the vein where exposed in the different levels is relatively quite regular, and although two main faults are in evidence in the 400-foot level, they do not materially interfere with mining operations. The displacement of the main fault first encountered at the 400-foot level decreases toward the west, and practically disappears a short distance from the shaft. Thus in this direction it has been possible to extend the development work on the vein below the 400-foot level.

On the 400-foot level to the west of the shaft, the vein is from 2½ to 8 feet in thickness, and is quite regular and well mineralized. In fact it is there very promising in appearance, quite as much so as in the upper levels. The shaft and levels, up to the time when visited early in October, had practically blocked out about 75,000 tons of ore, excluding the much faulted portions of the vein to the east of the shaft, and allowing for small stopes from which the ore had been mined and shipped. This 75,000 tons is what might be considered as ore in sight, that could be mined without difficulty. The total "probable ore" on the property would be several times this amount, as, particularly to the west of the shaft, the vein has every appearance of persisting to important distances both vertically and horizontally.

It is not known exactly what amounts of gold and silver this 75,000 tons will carry, but nevertheless considerable information concerning these values is available. This includes the results of the assays of a great number of samples taken both by the owners and prospective purchasers, these results having become known to the writer; also much valuable information concerning the values in this vein has been obtained at the government assay office in Whitehorse, where many samples from this deposit have been tested. Assays of $30 to $40 per ton in gold and silver are known to have been obtained, and much higher results have been reported. The writer has estimated as a result of all the information available, checked by personal observation during a number of visits, that the 75,000 tons of ore that is blocked out, will average in the neighbourhood of $15 per ton in gold and silver, or possibly slightly more. One estimate by the former management placed the average value of the entire vein so far explored, as low as $12 per ton in gold and silver. By a study of the mineralization of the vein, and with careful selective mining, no doubt important shipments can be obtained that will average over $20 and possibly between $25 and $30 per ton.

[1] The magnetic declination in Windy Arm district is generally about 32° 30′ east.

The vein affords, however, an ideal concentrating ore, and for the economical and profitable working of this deposit, it will be necessary to concentrate before shipping.

Equipment. A power plant has been installed at the mouth of McDonald creek, on the shore of lake Bennett, and within a few feet of the White Pass and Yukon Railway line. The plant includes a 100-horsepower boiler, and an electric generator which supplies power to the mine over a transmission line 4¼ miles long. At the mine considerable equipment has been installed, including a hoisting engine, a 40-horsepower motor, a 100-horsepower motor, 3-drill compressor, an 8-drill compressor, and a blacksmith and repair shop. Comfortable buildings have been erected, and a telephone line connects the mine with Caribou, and also with the power plant.

Summary and Conclusions. In the past the Big Thing vein has been mined, in most cases, none too economically, and the ore has then been hauled in wagons to Caribou, and shipped from there by rail and boat to coast points for treatment. The cost of operating in this way prohibits the development of the ore-body, at least on an extensive scale, as only a limited amount of the ore is rich enough to cover these expenses. To develop the property at all extensively, a concentrator will have to be built at some point near the mine workings, either actually at the mine, or on lake Bennett along the railway.

MONTANA.

General Statement. The Montana is one of the most important of the original Conrad properties, and is one of those at present under bond to the Harper Syndicate of Seattle. It is located on a bleak mountain side, high above timber-line, and about 3 miles from the Big Thing in a direction somewhat east of south; it is also about 2½ miles from the shore of Windy Arm at the nearest point, and about 3,700 feet above it.

Development. A drift has been driven along the vein for a distance of about 700 feet. An incline shaft has also been sunk which follows the vein for a part of its depth, but departs from it as the vein changes its dip. A short crosscut has been run from the bottom of the shaft to intersect the vein at that depth. Also on the adjoining Mountain Hero claim, a crosscut adit was run about 300 feet, and a 65-foot upraise was driven from the end of the adit, in the hope of cross-cutting the Montana vein at depth, but no important vein was encountered in the adit or upraise. This work was all done during the period of Col. Conrad's control. The work of the Harper syndicate up to the time of the writer's visit in October had been confined largely to digging the ice from the shaft and other workings, and the ice had not yet been completely removed. When this was accomplished, it was proposed to commence development work.

Vein. The Montana vein strikes north 43 degrees west (magnetic) and dips to the southwest at angles ranging from 10 degrees to 30 degrees. It occurs in a fissure intersecting greyish green to dark greenish, volcanic rocks which are dominantly andesites, basalts, and related types, and are thought to be of Cretaceous or Jurassic age. The vein ranges in thickness in most places from 2 to 5 feet, and is composed mainly of quartz with which is associated galena, pyrite, arsenopyrite, pyrargyrite, argentite, tetrahedrite, native silver, and lead carbonate. The principal values are in silver, but the pyritic portions also contain some gold. In places, the vein matter, especially adjoining the walls for thicknesses of 8 to 18 inches, is very highly impregnated with silver minerals, and assays $80 to $90 per ton; this ore could be shipped without sorting. The rest of the vein is of much lower grade, and requires concentration. On the whole, this is considered to be one of the most important veins in the Windy Arm district.

Equipment. A Riblet double-cable aerial tramway extends from Conrad on Windy arm, to the mouth of the crosscut on the Mountain Hero claim which adjoins the Montana. The tramway is 18,697 feet long, and has its upper terminal 3,464 feet above the lower. This tramway is of little service in its present position, but could be shifted so as to be of benefit to the Montana, or other claims in the vicinity. A 50-horsepower compressor plant with gasoline engine has been installed near the mouth of the Mountain Hero adit. The equipment also includes machine drills, a blacksmith shop, etc.; in addition comfortable stone buildings for offices, as well as mess and bunk houses, have been erected on the property.

M AND M.

The M and M is also one of the original Conrad claims which is at present under option to the Harper syndicate. The vein outcrops on the left bank of Pooly canyon near the top of the hill, and has been traced about 400 feet or possibly farther. It strikes nearly due north and south, and dips to the west at an angle of about 15 degrees. The vein also occurs in a fissure in andesitic rock, and is in most places from 6 to 12 inches in thickness. It is composed mainly of quartz with which occurs pyrargyrite (ruby silver), stephanite (brittle silver), freibergite, tetrahedrite (grey copper), and blue and green copper carbonates. This deposit is especially rich in the high grade silver minerals. A shipment of 5 or 6 tons of ore from the M and M, made by Conrad, is reported to have given returns of $165 per ton in gold and silver, the values being mainly in silver. Ore from this deposit can be handsorted to carry $100 to $200 per ton, but parts of the vein do not run over $20 or perhaps less.

A comparatively slight amount of work has been done on this property, including one main drift 90 feet long, and some shorter ones 12 to 15 feet driven on the vein, and also some surface cuts and trenches.

VENUS.

General Statement. On the Venus No. 1, only a small amount of work has been performed, but on the Venus No. 2, considerable exploratory work as well as an important amount of actual mining have been done. Thus locally the name Venus is generally used in referring to the Venus No. 2, and, unless otherwise mentioned, it will be here used with that meaning. The Venus No. 2 and Venus No. 1 adjoin, and the vein developed on each property is usually considered to be the same deposit.

The Venus is one of the most extensively developed of the original Conrad properties, but has, like the others, been closed for some years. It is also one of the properties at present under bond to the Harper syndicate, and is the one which they mainly worked during the past summer. Actual mining operations commenced on June 8, 1916, and some small shipments of ore were made.

Development. On the Venus No. 1, a shaft 52 feet deep has been sunk on the vein, and from the bottom of the shaft, drifts have been run about 50 feet in each direction. This comprises practically all the development work on the property.

On the Venus No. 2, two adits or so-called crosscut tunnels have been driven, which tap the vein at different depths. The upper adit is about 80 feet long, and encounters the vein at a depth of 75 feet below the surface. The lower adit is about 600 feet long, and cuts the vein at a depth of 263 feet below the level of the upper adit, measured along the slope of the vein. From the upper adit, drifts have been run distances of 108 and 88 feet to the south and north respect-

ively, which comprise the upper level of the mine workings. Some stopes also have been excavated from this level. From the lower adit, drifts have also been driven 583 and 622 feet to the south and north respectively. Several raises have been driven from this lower level, and stopes have been excavated, one of the raises running to the surface a distance of 213 feet measured along the vein. Two winzes have been sunk from the north and south drifts of the lower level which are said to be 235 and 400 feet deep respectively. Some drifting has also been done from these winzes which, however, were full of water when visited. This work, as just outlined, was mostly done for Col. Conrad, but it includes also that performed by the Harper syndicate up to the time of the writer's visit early in October last (1916).

Vein. The Venus vein occurs in a fissure, in places of a compound nature, which traverses andesitic rocks believed to be of Cretaceous or Jurassic age. These rocks are in places decidedly tuffaceous in character, and, especially in the vicinity of the Venus, are quite reddish in colour, due to the presence of iron oxide. The vein strikes about north 10 degrees east (astronomic), has a dip to the west, into the hill, ranging from nearly flat to approaching 60 degrees. The dip in the workings on the Venus property, however, is in most places between 25 and 30 degrees. The vein itself has been produced mainly by direct deposition in open crevices, as is indicated by the pronounced banding and comb structures, but it is also partly the result of replacement of the wall rock. The fissure containing the vein is in most places of a compound nature, i.e. it is really several close parallel fissures, between which is more or less crushed and broken rock. The vein as a whole is thus usually well defined by two main fault planes from a few inches to 8 or 9 feet apart. Between these is the vein material, and more or less replaced wall rock, occurring in bands parallel to the walls, or in irregular fragments or blocks. The actual ore material ranges from an inch to 7 feet in thickness, but is, in most places where exposed in the underground workings, from 2½ to 3 feet thick. At the ends of both of the lower drifts it is exceptionally thin, however. At the end of the south drift it pinches to less than an inch, and in the north drift for some distance before the end is reached it is only from 2 to 6 inches thick. These pinches do not probably indicate the approaching ends of the vein, for the reason that on the surface the vein is strong and well mineralized for a considerable distance past the ends of the drifts.

The vein minerals include mainly quartz, galena, pyrite, and arsenopyrite, but some jamesonite, yukonite,[1] chalcopyrite, and copper glance also occur, as well as the oxidation products, lead carbonate, and green and blue copper stains. The values in the veins are mainly in silver which occurs dominantly associated with the galena. The galena is generally finely textured and markedly cubical but in places it is fibrous, and has been mistaken for stibnite. Important amounts of gold also occur, which appears to be for the greater part associated with the arsenopyrite. The gold and silver contents vary greatly. A few samples have been obtained which ran $200 or over per ton in gold and silver, but the information available, including the assay returns of a great many samples, taken both by the operators and by prospective purchasers, the results of which have become known to the writer, show the vein in most places to carry from less than one ounce to over 100 ounces in silver per ton, and from a trace to about $100 in gold; the gold, however, seldom exceeds $50, and is generally under $25. Where the ore is unaltered, it contains up to 15 per cent lead, and from a trace to nearly 1 per cent copper. The ore in the higher grade shoots averages from $30 to $50 per ton in all values. Much of the vein, however, is very low grade, running from almost nothing to about $20 per ton. During the past summer,

[1] A hydrated arsenate of calcium and iron. See Johnston, Robert, A. A., "A list of Canadian mineral occurrences." Geol. Surv., Can., Mem. 74, 1915, p. 240.

up to the time when visited early in October, 1916, about 300 tons of sorted ore had been shipped to Anyox, B.C.; this averaged about $70 per ton. It is claimed that Conrad mined about 6,000 tons of ore from the Venus, part of which was shipped to the smelters at Ladysmith and Tacoma, the remainder being treated in the Venus mill.

Equipment. A concentrating mill has been built on the shore of Windy arm immediately below the mouth of the lower adit, and was completed during the summer of 1908. It was said to have a capacity of 100 tons a day. The equipment includes a 100-horsepower boiler and a 75-horsepower engine, for generating the motive power, also a partly installed hydraulic plant to obtain power from Pooly canyon. The concentrating equipment embraces a grizzly, Blake crusher, trommels, high-speed rolls, a Huntington mill, jigs, four Callow screens, six Callow settling tanks, three Wilfley tables, and two Frue vanners. The mill was run only a short time when losses in the slimes were found to be very high; as a result, it was closed, and has not since been in operation.

An aerial two-bucket tramway 1,525 feet long, connects the lower adit with the mill—the upper terminal being 958 feet above the lower.

The equipment also includes an engine and compressor for operating machine drills, a hoist, machine drills, ore cars, blacksmith shop, etc. Comfortable bunk and cook houses have also been erected on the beach near the workings.

Freight Charges. All ore at present shipped from the Venus to outside points has to be sacked owing to water transportation facilities between the mine and the railway at Caribou, and also because of the limited reloading equipment at Caribou. The summer freight rate on this sacked ore from the Venus to the smelter at Anyox, B.C., during the past summer (1916) was $5.50 per ton.

Summary and Conclusions. The Venus is being operated at present under a number of disadvantages. The ore has to be sorted on the property and shipped to coast smelters for treatment. If the ore could be successfully concentrated before shipping, a great economy would be effected, and more of the vein could be profitably mined. The ore, however, contains brittle and even oxidized minerals, to such an extent that any attempt at water concentration will result in heavy losses in slimes, unless a cyanidation plant be installed for treating the tailings, and this would be feasible only with a large tonnage blocked out. Furthermore, at present, all ore being shipped has to be sacked. If arrangements could be made for shipping the ore without sacking it, a considerable saving would result, but this extra cost seems difficult to avoid.

It is difficult to estimate at all closely the ore blocked out that can be profitably mined under existing conditions. There is, however, considerable information available on this point including the returns for various ore shipments, and the assays of a great number of samples taken both by the operators and prospective purchasers, the results of which have become known to the writer. This has all been checked and supplemented by personal observations by the writer. From all the information available, there would seem to be about 20,000 tons practically in sight. If the ore could be concentrated with a satisfactory saving, and at a reasonable cost, this ore estimate would be increased three or four times. Also, as the vein has the appearance on the surface of being persistent, the amount of "probable ore" on the Venus No. 1 and Venus No. 2, is several times the "ore in sight."

DAIL AND FLEMING GROUP.

General Statement. A number of claims, that since 1905 have been generally known as the Dail and Fleming group, are located along the west side of Windy arm, immediately to the south of the Venus. These claims include the Venus

Extension, Red Deer, Humper No. 1, Humper No. 2, Nipper No. 2, and the Beach, all of which with the exception of the Nipper No. 2, were staked in 1904 by George Dail and I. E. Fleming. Later Dail and Fleming found that there was vacant ground between the Venus Extension and the Beach and in 1905 they staked the Nipper No. 2 to cover it. An interest in the group was later acquired by John Miller. In 1906 these claims were bonded to the Anglo-American Consolidated Company of Seattle for two years. That company sunk the Venus Extension shaft, and drove drifts from it, and also did the work on the Nipper No. 2. At the expiration of the bond, terms could not again be agreed upon, and the property reverted to the owners. They immediately gave a three years' option to Col. Conrad who did some work and placed considerable machinery on the ground for driving a 500-foot crosscut adit. He, however, failed to do the work as agreed, and in 1910 forfeited his option and machinery. Since that time practically the only development performed is the annual assessment work required by the government, which has been done by the owners.

Recently the ownership has changed. The claims have been divided into two groups, the Venus Extension group, and the Humper group. The Venus Extension group includes the Venus Extension, Red Deer, and Humper No. 1, and is owned by I. E. Fleming and John Miller. The Humper group, embracing the Humper No. 2, Nipper No. 2, and the Beach, is reported to be owned by John Miller and Mrs. M. Watson.

Development. The bulk of the development work on these claims has been performed on the Venus Extension claim which adjoins the Venus No. 2; but the following comprises practically all the work that has been done on the entire group.

On the Venus Extension and near the northern end of the claim, an incline shaft has been sunk on the vein for 120 feet, and at a depth of about 40 feet, drifts having an aggregate length of about 45 feet have been run in each direction. About 200 feet from the south end of the claim an open-cut has been run in about 30 feet, and has exposed the vein below the loose overburden. Near the south end of the claim, a crosscut adit, or so-called tunnel, was driven diagonally 55 feet to the vein, and thence continued as a drift along the vein 150 feet farther, making a total length of 205 feet. Some short cross drifts have also been driven from the main drift and a few small surface cuts have been dug.

On the Beach and Red Deer claims, a small amount of surface work only has been done.

On the Nipper No. 2 a number of pits and cuts have been excavated in the hope of finding the extension of the Venus vein. About 85 feet from the south side of the claim, a crosscut was driven 45 feet and a winze was sunk 30 feet, from the bottom of which a short drift was run on a narrow, apparently low grade vein 6 to 8 inches in thickness.

On the Humper No. 1, and near the south end of the claim a pit was sunk 16 feet on the Humper vein. About 300 feet southwest of this pit, and near the northern end of the Humper No. 2, an open-cut has been run 20 feet into the same vein and from the bottom of the open-cut, a winze has been sunk about 16 feet. From the open-cut, about 40 feet of drifting has been done and from the drifts stopes have been raised to the surface.

Veins. Three principal veins have been found to occur on these claims. These are known as the Venus, Humper, and Red Deer veins respectively.

The Venus vein is the same as the one developed on the Venus property, and has been traced from the Venus No. 2 almost entirely across the Venus Extension, but so far as is known has not been found as yet on the adjoining property to the south, the Nipper No. 2. What is known concerning this vein on the Venus Extension, has been mainly derived from the shaft and main adit

or drift. The vein possesses the same main characteristics as that on the Venus No. 2, and ranges in thickness from a few inches to 4 feet, being generally from 18 to 30 inches. On the Venus Extension, however, the vein is intensely leached and oxidized. In the drift or adit, practically no sulphides occur for the first 130 feet, after which some pyrite, arsenopyrite, and galena appear. The considerable degree of oxidation is here partly accounted for by the fact that the drift has a diagonal course into the hill and thus gains depth very slowly. The attitude of the vein as exposed in the drift is undulating, but in a general way is nearly flat. The vein in the drift also ranges in thickness from 6 inches or less, to about 30 inches, being in most places under 20 inches. The gold content is in most places from $5 to $25, but occasional assays have been obtained running to about $100. The average silver content is believed to be generally under 10 ounces per ton. In the shaft the vein is also greatly oxidized, but pyrite, arsenopyrite, and galena occur; also yukonite, lead carbonate, and some bright red and yellow minerals which have proved to be realgar (arsenic monosulphide, AsS) and orpiment (arsenic trisulphide As_2S_3) respectively. The vein in the shaft ranges in dip from 15 to 35 degrees, and has a thickness in most places of 10 to 36 inches. The gold and silver content is about the same as in the drift, being slightly higher if anything. The gold ranges from about $2 to $50, but is generally under $25, and is believed to average more nearly $15 per ton. The silver runs from less than an ounce to over 100 ounces, but, except for occasional rich spots, probably does not average over 5 to 10 ounces per ton. The lead value ranges from about $1 to $30, averaging in unleached portions of the ore, between $4 and $5 per ton. The total values in gold, silver, and lead run from about $5 to over $100, but the average for this vein on the Venus Extension is rather low. Important amounts of ore occur, however, that could be mined, hand sorted, and treated at a profit. An attempt should be made to open up this vein at a depth below the oxidized and leached zone, the best method for doing so, being probably by a crosscut adit and drifts.

The Humper vein also occurs in a fissure traversing andesitic rocks of probably Mesozoic age, and has been traced for about 600 feet. The strike varies from east and west to about north 60 degrees east (astronomic), and the dip ranges from 35 degrees to 65 degrees to the north and northeast. The thickness of the vein is from 10 to 24 inches in most places where explored. The gangue of the vein is chiefly quartz with which is associated argentite, pyrargyrite (ruby silver), stephanite (brittle silver), galena, pyrite, and some native silver. Parts of the vein, at least, are very rich in silver, but the average gold and silver content is not known at all closely.

The Red Deer vein is also in a fissure in the Mesozoic andesitic rocks; it strikes about north 30 degrees east (astronomic), and dips to the northwest at an angle of about 50 degrees. It is, where exposed, also from a few inches up to about 3 feet in thickness, and is composed mainly of quartz which carries pyrite, galena, and various high grade silver minerals. This vein on the Red Deer claim is supposed to be the extension of the high grade vein on the Ruby Silver, a claim held by private parties, which has not been worked for a number of years. Very little is known concerning the Red Deer vein, as it has been so slightly developed.

Equipment. The machinery placed on the property by Col. Conrad during the term of his option is still there. This includes a boiler, compressor, two small air receivers, piping, rails, mine cars, blacksmith tools, etc. Several log cabins have been built on these claims, most of which are on the shore of Windy Arm.

Summary and Conclusions. The veins on these claims with the exception of the Venus vein, have been very slightly explored, and mainly only the upper oxidized and leached portion of the Venus vein has been developed. Further,

when attempts were made a few years ago to develop the ore deposits on these claims, the freight rates charged by the White Pass and Yukon railway and boat lines were much higher than at present. There is good reason to believe that under existing conditions, portions of the Venus and Humper veins, and possibly the Red Deer vein, under good management, and with hand sorting, would pay to mine and treat. If a concentrator were built on Windy arm, or the one already there were remodelled to successfully treat these ores, it is believed that an important tonnage and revenue would result.

INVESTIGATIONS IN BRITISH COLUMBIA.

(*Chas. W. Drysdale.*)

INTRODUCTION.

The geological field work of 1916 was devoted mainly to economic investigations in the Coast and Selkirk ranges of the British Columbia Cordillera. One week (June 10 to 16) was spent making a hasty reconnaissance in the vicinity of Anyox and Portland canal in order to plan for future work there. The writer wishes to thank the officials of the Granby Consolidated Mining and Smelting Company, the chief operators in the region, for many courtesies extended during his visit and for their kind co-operation in the field work. One month (June 20 to July 20) was spent in Lillooet district revising and investigating more closely the structure of the northern portion of Bridge River map-area, examining recent mine development, and hunting for new fossil and mineral localities. The data collected during the field seasons of 1915 and 1916, along with the final geological map, will be included in a memoir now in preparation on the geology and mineral deposits of Bridge River map-area. The Index molybdenite mine on the divide between the heads of Phair (Cottonwood) and Texas creeks was visited on July 18 and 19. Four hours were spent in the examination of the geological occurrence of the ore on the property itself.

The remainder of the field season (July 22 to October 10) was devoted to reconnaissance and detailed mine work in Kootenay district. A traverse was made across the Purcell range from Marysville to Creston via White Grouse mountain and Goat river, thence to Salmo, Ymir, and Nelson by way of the Dewdney trail up Summit creek and down Lost creek to Salmon river. The time from August 14 to October 6 was spent in completing the geology of Slocan mining area. The memoir on the district now being prepared for publication is mainly the work of O. E. LeRoy, now a captain in the Canadian expeditionary force in France. It will include, besides an account of the geology and ore deposits of the region illustrated by maps and drawings, a description of the mines and prospects within the area mapped as well as a few of the more important outlying properties. Sincere gratitude is expressed to the mine operators and prospectors in Slocan district for their interest and help in carrying on the field work.

The return trip from Kaslo over the Purcell range was made from Crawford Bay over Rose pass and down the West Fork of the St. Mary river to Marysville.

In the field work the writer had the able assistance of M. F. Bancroft whose familiarity with many phases of the Kootenay work aided materially in its prosecution.

Anyox Map-area, Skeena Mining Division.

Anyox map-area covers about 20 square miles of mineralized Coast Range country on Observatory inlet parallel to Portland canal. The area includes both the Hidden Creek and Bonanza mines of the Granby Consolidated Mining

and Smelting Company. F. S. Falconer of the Geological Survey completed the topographic map of this area during the field season of 1916, his detailed map being plotted on the scale of 1,000 feet to 1 inch with topography shown by contours at 50-foot intervals.

The Hidden Creek mine, which is now one of the largest copper mines in the British Empire[1] was first examined in 1911 and again in 1913 by R. G. McConnell, Deputy Minister of Mines. McConnell's reports on the geology of the region were published in the Summary Reports of the Geological Survey for the years 1911 and 1913.

In June, 1916, the Granby Company mined and smelted about 2,500 tons of ore per day and employed over 1,600 men at the mine and smelter. The smelter is about 2 miles distant from the mine, at the seaport of Anyox, on Granby (formerly Goose) bay.

The ore is a massive sulphide composed of pyrite, pyrrhotite, and chalcopyrite in a gangue of country rock, and averages about 2·37 per cent copper and 34 cents per ton in gold and silver. The ore occurs in irregular replacement shoots, elliptical in section, and varying in width from 50 to 240 feet and in length from 880 to 1,600 feet. No. 1 ore-body strikes in a northeasterly direction and dips to the northwest at an angle of 65 degrees; No. 2 ore-body strikes northwest, dips 45 degrees to the northeast and the ore is of a siliceous composition. The ore has been tested by diamond drilling to a depth of 300 feet below sea-level or to a vertical distance of 1,250 feet below the outcrop. The ores from the various shoots vary considerably in silica, iron, and alumina contents, depending largely upon the original composition of the replaced country rock. The wall rocks are crushed and altered argillaceous and greenstone schists intruded by dykes of different types most of which were derived from the underlying Coast Range batholith.

Bridge River Map-area,[2] Lillooet Mining Division.

GENERAL GEOLOGY.

During the past field season fossils were found for the first time within the limits of the map-area; one fossil locality is on Shulops mountain and another is on the ridge to the northwest of, and overlooking Tyaughton lake. The positions of the fossil horizons are indicated on the accompanying structure section which follows a line drawn from the west boundary of the map sheet 2 miles north of Gun creek to a point on the north boundary 7 miles west of the northeast corner of the sheet (Figure 2). The section is extended along the same line to a point 10 miles beyond Yalakom river. E. M. Kindle of the Geological Survey, who examined the fossils, submits the following preliminary report: "The lot represented by numbers B32, 33, and 34 (Shulops Mountain locality) contains nothing which would warrant any statement regarding the horizon

[1] The estimated ore reserves remaining, after deducting the 1,270,484 tons shipped up to June 30, 1916, are given in the annual report of the Granby Consolidated Mining, Smelting, and Power Company as follows:

Ore body	High grade Tons	Low grade Tons	Total Tons
No. 1	4,064,110	2,846,400	6,910,510
No. 2	3,949,000	4,334,735	8,283,735
No. 3	1,329,020	1,320,000	2,649,020
No. 4	74,255	100,500	174,755
Total	9,416,385	8,601,635	18,018,020

Underground development amounts to 5·2 miles of drifting and raising, whereas the total diamond drilling up to June 30, 1916, is 9·4 miles. "The cost per ton of ore mined, crushed and delivered on the railway cars, amounted to 99·6 cents. This cost includes all underground development, diamond drilling, handling of waste and overburden, management and all other operating charges." The ore reserves at the Bonanza mine are estimated to be 900,000 tons of similar grade ore.

[2] See Geol. Surv., Can., Sum. Rept., 1915, for description and geological diagram, pp. 75–85.

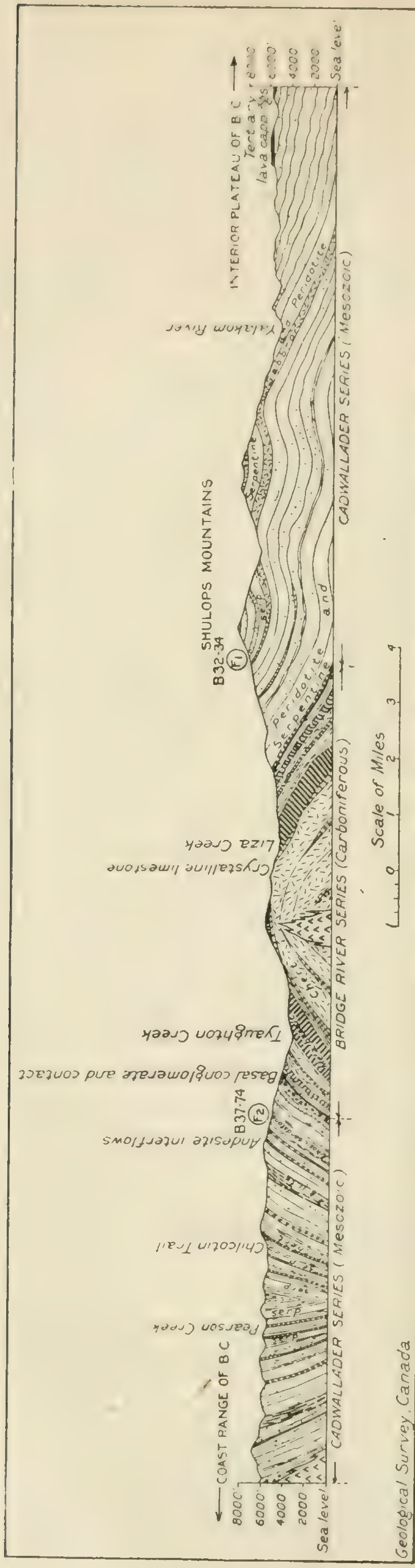

Figure 2. Structure section through northern portion of Bridge River district, B.C.

represented. The youngest fauna in the collection is that represented by numbers B37, 38, 40, 41, 47, 58, 70, and 74 (Tyaughton Lake locality) (Figure 2). This is a pelecypod fauna of Mesozoic age associated with fragmentary plant remains embedded in an arkose sandstone. The fauna is either of Lower Cretaceous or upper Jurassic age. The forms present do not represent characteristic or index species of either of these horizons and it is not at present advisable to offer a more precise opinion."

The fossil plants (B 35–78) found along with the pelecypod fauna at the Tyaughton Lake locality were submitted to W. J. Wilson of the Geological Survey, who reports on the small collection as follows: "These plant remains are in a somewhat coarse arkose sandstone and are consequently poorly preserved. They consist mostly of fragments of stems and cycadaceous leaves and two small specimens, B–62 and B–55, that may be the impressions of fruit. There is one fragment of a leaf, B–36, about 8 cm. long and 2 cm. broad, which has most of the characteristics of *Zamites megaphyllus* (Phillips) as described by Seward and Knowlton. Unfortunately it is incomplete at the base so that its attachment to the rachis is not shown. Knowlton mentions that this species occurs with others in the Cape Lisburne area, Alaska, and points out that the age of the rocks is undoubtedly Jurassic belonging either to the upper part of the middle Jurassic or the extreme lower portion of the upper Jurassic. As far as the Bridge River Area specimens indicate anything they point to a Jurassic age for that area, but they are altogether too fragmentary and poorly preserved to base definite conclusions on."

A traverse was made of the ridge extending from the headwaters of Eldorado creek to Tyaughton creek and the same series of formations was found there that compose the Cadwallader series farther south and west; the only difference is in the degree of metamorphism which is not quite so intense in the Eldorado section owing to the absence of large granitic masses. Furthermore, there is evidence in the presence of drag and other structures of an extensive fault along the line of Gun and Tyaughton lakes. This has overthrust the fault block northwest of the fault plane, eastward, and heaved it to the northeast thus exposing a slightly higher and younger Mesozoic series than the Cadwallader series south of the fault plane.

ECONOMIC GEOLOGY.

Gold Quartz.[1]

The Pioneer, Coronation, and Lorne gold mines were being worked and the production of lode gold increased from 31 ounces in 1915 to 2,625 ounces in 1916.[2]

The mining and milling plant at the Pioneer was completed and in operation. Much of the machinery had been hauled in over the snow during the previous winter from the Pacific Great Eastern railway at Bridge River crossing. Power for the plant is furnished by a 195-horsepower Canadian turbine water wheel driven by water brought from Cadwallader creek through a 4-foot by 5-foot flume 1,700 feet long. The turbine is installed about 20 feet below the foundation of the mill. Air for rock drills, hoist, and blacksmith shop is supplied by a 12-inch by 12-inch Rand compressor capable of operating five drills. The ore from the mine is hoisted to the surface in one-half ton capacity skips which empty into an ore bunker at the top of an incline gravity chute. The chute conveys the ore to the level of the charging floor of the mill where it is trammed to the grizzly bar and put through a Dodge crusher and Bryan rolling-mill, the mill

[1] For preliminary description of properties, see Geol. Surv., Can., Sum. Repts., for 1911, 1912, and 1915.
[2] Figures from B.C. Bureau of Mines.

having a capacity of 20 tons every 24 hours. The Bryan mill has a 40-mesh screen and plane amalgamation is used, the plate being three-fourths of an inch thick. A sawmill and electric light plant have been built. The owners intend making additions to the mill in order to increase its daily capacity to 40 tons. This will include the installation of a concentrating table to save the concentrates.

A two compartment vertical shaft has been sunk 100 feet on the main vein and drifts were being commenced. At 40 feet in depth, a slip was encountered and the shaft entered the hanging-wall of the vein. The bottom of the shaft was in Cadwallader greenstone (diabase) and paying quantities of gold are reported from the vein at this level. In many places the greenstone appears to grade into the Cadwallader augite-diorite or gabbro and it probably represents a fine-grained, chilled variety of the diorite which so far has proved to be the gold formation of the camp.

Since the time of visit a drift 150 feet long was made west of the shaft and one 25 feet long east of the shaft. The vein at this level (about 100 feet below the collar of the shaft) averages 3 feet in width and contains the characteristic ribboned quartz of the camp. Up to December 1916 the total assay office returns on the gold recovered by amalgamation from the Pioneer mine are given as $20,500. The owners report a mining cost of $2 per ton and a milling cost of $1 per ton. The cost of getting food and supplies from railway to mine, a distance of 54 miles, is 3 cents per pound.

Development work was being continued at the Coronation mine, under the superintendency of Mr. Wm. Haylmore, and a small lot (about 140 tons) of ore had been put through the 10-stamp mill. The Lorne mine and mill were being operated during the summer by Mr. Arthur F. Noel and a small staff of men who were reported in November to have brought out gold bullion valued at $5,800. The Golden Dream Mining Company was carrying on placer mining operations near the mouth of Hurley river. In addition, annual assessment work on quartz claims and placer mining by individual miners was in progress, mainly in the Cadwallader camp and on Hurley river and Tyaughton creek.

Magnesite.

In the course of geological field work in 1915 magnesite was found at several localities in Bridge River district, everywhere in association with serpentinized peridotite of Mesozoic age.[1] During the past field season the writer found an outcrop of magnesite measuring 52 feet wide by 48 feet long near the southwest end of Liza lake. The material included both massive and crystalline varieties, in places cut by numerous veinlets of clear chalcedonic quartz. Other smaller exposures of magnesite of similar quality were noted on the same hillside. They are separated by areas of wash probably underlain by decomposed serpentine. There is considerable float of this valuable non-metallic product in this portion of the valley and no doubt future prospecting in the serpentine belt will disclose other occurrences. Cinnabar, chromite,[2] platinum, and gold should also be searched for by prospectors in this belt which appears to be the extension in British Columbia of the California magnesite belt.

The elevation of the main outcrop measured is about 4,300 feet above sea-level. The locality[3] is over 30 miles from the Pacific Great Eastern railway at Bridge River crossing on Seton lake and the deposits probably could not be worked at a profit under present conditions. In the future, with better transportation

[1] Geol. Surv., Can., Sum. Rept., 1915, pp. 81, 83–84; with outline map.
[2] Geol. Surv., Can., Sum. Rept., 1915, p. 83.
[3] See map accompanying Geol. Surv., Can., Sum. Rept., 1915, for position of deposit with respect to trails and wagon road.

facilities and a greater demand by western manufacturers for this material, the deposits might be profitably mined.

The following analyses of magnesite made by the Mines Branch are representative of the Bridge River material:

Analyses of Magnesite from Bridge River.

	1	2	3
MgO	43·42	42·20	28·14
CaO	0·46	3·25	18·48
FeO	0·56	......	......
Fe_2O_3	0·25	0·95	1·64
Al_2O_3	0·23	0·59	0·92
CO_2	47·28	48·55	45·18
SiO_2	7·46	4·08	4·08
H_2O (above 105°C)	0·58	......	......
H_2O (below 105°C)	0·10	......	......
Total	100·34	99·62	98·44

1. From northeast side of valley near Liza lake. Collected in 1915. Analyst, N. L. Turner.
2. Massive variety from northwest end of Liza lake. Collected in 1916. " D. M. Stewart.
3. Crystalline dolomitic variety from same locality. Collected in 1916. " D. M. Stewart.

Irregularity and uncertainty of extent is a characteristic common to nearly all the known magnesite deposits of the world and the Bridge River deposits are no exception to the rule. They resemble closely the California deposits and may be safely correlated with them both in age and origin. The field relations, however, suggest that the Bridge River deposits were formed through deep-seated, hydrothermal alteration of the peridotite[1] and serpentine by juvenile carbonate waters rather than through surface alteration by atmospheric waters containing carbon dioxide.

The magnesite weathers less readily than the much altered serpentine in which it occurs and on that account stands out in bold relief. Both veins and irregular masses of various sizes and degrees of purity are found. The pure white variety weathers buff in colour owing to slight staining by iron oxide. The impure varieties weather in brilliant shades of red and contain iron oxides, silica, mariposite (?), and serpentine in varying amounts and proportions. In many places the magnesite is cut by veinlets of clear chalcedony which, however, could be readily separated from the pure carbonate in mining.

Uses and Market Conditions for Magnesite.[2] Magnesite is used in three forms: crude or unburned; burned to the caustic state (i.e. not thoroughly calcined); and dead-burned.

[1] A chemical analysis of a similar peridotite from Yale district, B.C., made by W. F. Hillebrand, is as follows and shows the high content of magnesia:

MgO 45·23; CaO 0·35; FeO 6·69; Fe_2O_3 3·42; Al_2O_3 0·29; CO_2 1·10; SiO_2 38·40; Na_2O 0·08; P_2O_5 trace; H_2O- 0·24; H_2O+ 4·11; S 0·06; Cr_2O_3 0·07; NiO 0·10; MnO 0·24; Total 100·38.

The sample was about two-thirds olivine and one-third serpentine, with some magnetite, calcite, and magnesite as accessories. U.S. Geol. Surv., Bull. No. 591, p. 210.

[2] Hess, F. L., "The magnesite deposits of California, 1908", U.S. Geol. Surv., Bull. No. 355.

Gale, H. S., "Late developments of magnesite deposits in California and Nevada, 1912", U.S. Geol. Surv., Bull. No. 540 (S).

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"Magnesite production and markets", Min. and Sc. Press, Aug. 12, 1916, pp. 234–235.

Grosvenor, Dr. Wm. M., "Metallic magnesium industry", Eng. and Min. Jour., April 8, 1916, vol. 101, No. 15, pp. 652–653.

Wilson, M. E., "The magnesite deposits of Grenville district, Argenteuil county, Quebec", Geol. Surv., Can., Memoir 98 (in press).

The raw or crude magnesite contains 52·4 per cent CO_2, in contrast with the 44 per cent content of limestone and is, therefore, preferable to calcium carbonate for the manufacture of carbon dioxide gas. The amount of heat required to drive off the carbon dioxide is much less than that needed for limestone. Furthermore, the residual magnesia left after calcination is more valuable than lime and, if pure enough, can be calcined "caustic" and made into magnesium salts and compounds. This use of magnesite, however, is decreasing owing to the difficulty, in many cases, of disposing of the residue which contains too high a percentage of carbon dioxide for use even as caustic magnesia and, therefore, requires reburning at a higher temperature. The calcined residue from many magnesites is too impure to be used in the manufacture of the various compounds of magnesia used for medicinal and other purposes, but this would probably not be the case with the Bridge River magnesite.

Caustic magnesia produced by calcining magnesite in kilns at a temperature of about 1,100 degrees Centigrade, may contain 3 or 4 per cent of carbon dioxide. It readily combines with a few reagents, such as magnesium chloride. When mixed with magnesium chloride it forms a strong cement, known as "Sorel cement," "oxychloride cement", etc., which is used in the making of dust-proof floors, stairs, sinks, artificial marble, plaster for fireproof partitions, wainscoting, tiles, millstones, and polishing wheels. Sawdust, sand, talc, cork dust, ground quartz, colouring matter, and other substances are used as fillers and pigments in the cement mixtures. Floors made of magnesite cement are smooth, even, and may be laid in thin sheets over large surfaces without cracking. The cement takes colour readily and is as susceptible to a good polish with oil or wax as a wooden floor. It may be laid in a plastic state on wood or concrete.

Caustic magnesia made from the massive magnesite of Bridge River, being practically free from lime, would be highly suitable for the purposes mentioned.

Magnesite burned to a temperature of 1,700 degrees Centigrade is deadburned and contains less than one per cent of carbon dioxide. It has been calcined so thoroughly that there is no deterioration or reversion through the absorption of carbon dioxide on exposure to the air. This form of magnesite is used as a refractory material for a number of purposes such as lining furnaces, for basic metallurgical processes, for crucibles, cupels, and refractory bricks as employed in constructing the bottoms of open-hearth steel furnaces, copper converters, reverberatories, settlers, electric and other melting, heating, and welding furnaces. The imported crystalline variety of magnesite, which is used almost exclusively in metallurgy, generally contains 3 to 4 per cent of silica, 6 to 8 per cent iron oxide, and 4 per cent lime. Even the impure grades of Bridge River magnesite might make brick which would compare favourably with the imported Austrian product.

Magnesite, raw or calcined, is used in the manufacture of magnesium compounds, such as epsom-salt (magnesium sulphate) and magnesium chloride. The manufacture of the so-called "cold water" and "fire-retarding" paints and concrete waterproofing involves the use of magnesia with magnesium chloride. Magnesia mixed with such substances as asbestos and infusorial earth[1] also enters into a preparation for insulating boilers and steam pipes. To prevent scale in boilers in which sulphurous water is used powdered magnesite is occasionally employed as it combines with the sulphur in the water to form magnesium sulphate (epsom-salt) which is highly soluble. Calcined magnesite is converted into magnesium bisulphite for use in digesting and whitening wood pulp in paper mills. The magnesite of Bridge River district would be well adapted for this purpose. In the sulphite process of paper-making the wood (mostly of coni-

[1] See p. 53.

ferous trees) is boiled with a disintegrating agent so that it breaks down into a mass of pulp which is afterward rolled into paper. The disintegrating agent is sulphurous acid or bisulphite of calcium or magnesium. Magnesium bisulphite is more soluble than calcium bisulphite; it dissolves the non-cellulose matter more completely, and it has an additional advantage in that the residues left in the stock when it is used are not afterward injurious to sizing agents. Ground crude magnesite is also used to a limited extent in the rubber industry. A basic carbonate, a chemical product of magnesite, known as light magnesia or magnesia alba, is said to make an excellent absorbent for nitroglycerine in the manufacture of dynamite, as it does not readily allow the nitroglycerine to "sweat" out.

Metallic magnesium is usually recovered by the reduction of the chloride but it can also be obtained by the reduction of the oxide or carbonate. The chief uses of magnesium are: (1) scavenging alloys—making denser, cleaner, stronger and more homogeneous alloys; it is valuable in aluminum, nickel, copper, brass, bronze, and special steels, because of its intense avidity for both oxygen and nitrogen; (2) illumination—as in military operations for shrapnel trailers, star bombs, flare lights, etc., and in photography for flash lights.

In aluminum castings 2 per cent of magnesium cleans the aluminum, almost doubling its tensile strength, quadrupling its resistance to shock or jar, and reducing the cost of machining by more than 50 per cent. This is of great importance in connexion with the construction of aeroplanes and dirigible motors, high speed engines of every type, and in all machinery or structures where strength, with a minimum of weight, is required.

The price of magnesium before the war was steady at about $1.45 per pound, but rose from $2.50 shortly after the beginning of the war to as high as $7.50 per pound. The price in December 1916 was $3.50 per pound for guaranteed 99 per cent magnesium. The price of crude magnesite ranged from $5.50 to $12 per ton during 1915 and 1916. Calcined magnesite sold at a wide margin from $20 to $60 per ton. California calcined magnesite in bulk sold for $25 to $30 per ton f.o.b. San Francisco or other California points. When ground and packed in barrels, the price of calcined magnesite ranged from $40 to $60 per ton. About 2½ tons of crude, produce 1 ton of calcined magnesite so that the calcining is commonly done at the mine in order to lessen shipping cost. In California, facilities for saving the carbon dioxide gas are seldom provided. In Greece, however, the gas is saved by calcining in retorts and is used in the manufacture of effervescent beverages.

There is no duty in Canada and in the United States on raw or calcined magnesite nor on the salts of magnesium. Under normal market conditions the sales of the material would be confined to the Pacific Coast and western provinces as the high freight rates to the eastern provinces would preclude its shipment in competition with the Grenville, Quebec, magnesite, or imported products.

Yukon Magnesite. Beds of magnesite weathering red and rarely exceeding 10 feet in thickness, are reported by D. D. Cairnes from Stony fork of Black river. The beds are in places interbanded with slates and dolomites in layers less than 2 feet in thickness[1]; R. G. McConnell found magnesite on the east side of Yukon river, about 1½ miles above Indian river, also on the east side of Big Salmon river a tributary of the Lewes, just below Island lake, "where it occurs in the form of heavy bands—which are, in some instances, in parts, 50 feet or more in thickness—associated with dark and light coloured, partly altered, slates, greenish schists, and serpentine."[2]

[1] Geol. Surv., Can., Sum. Rept., 1911, p. 32.
[2] Geol. Surv., Can., Ann. Rept., vol. XI, pp. 15, 16R.

British Columbia Magnesite. Impure, brown weathering outcrops of magnesite were reported by J. C. Gwillim "along the shore of Atlin lake near the mouth of Pine creek, also on Taku inlet west of Taku mountains. It is met with in smaller areas about the head of McKee creek also on the mountains between Ruby, Boulder, and Birch creeks."[1] A white, earthy hydromagnesite containing 19 per cent combined water occurs near the town of Atlin, as superficial beds rarely more than 5 feet or less than 1 foot in thickness and varying in areal extent from an acre to 18 acres (in one case). The aggregate tonnage of the known areas has been estimated by G. A. Young at 180,000.[2]

Magnesite is reported by R. G. McConnell from near Germansen creek, Omineca river, where it occurs with dolomite and serpentine interbedded with green schistose ash rock.[3]

Magnesite is reported as occurring near Illecillewaet.[4]

A deposit of hydromagnesite similar to that at Atlin, is reported from 108-mile house on the Cariboo road 93 miles north of Ashcroft "where it forms three or four deposits of from 50 to 100 feet across, standing a foot or more above the level of the surrounding surface. It is also traceable from the one to the other of these deposits over an area of probably 50 or more acres of ground.[5]

Ontario Magnesite. A blue ferruginous magnesite associated with pyrite has been reported from Lac des Milles lacs, Thunder Bay district.[6]

Quebec Magnesite. Extensive deposits of magnesite occur at Grenville, Argenteuil county. It is the crystalline variety and high in lime content.[7]

Magnesite to a stated width of 20 yards was reported in 1847 to occur in Brome county at Bolton in lots 17 and 24, range IX; and at Sutton on lot 12, range VII, in a bed one foot thick in grey mica schist; and on lot 24, range IX, Bolton, in argillites in a bed of unknown thickness.[8]

New Brunswick Magnesite. Magnesite is reported to occur in St. John county, near West Branch, in a vein several feet wide in grey chloritic schist.[9]

Nova Scotia Magnesite. Magnesite has recently been found in Inverness county near Orangedale. It is a brown crystalline variety. The Nova Scotia Steel and Coal Company own the property and have mined 30 tons from the deposit.[10]

Volcanic Ash (Siliceous Earth).

The volcanic ash or andesitic pumice[11] which occurs in great quantity as the most recent formation in the Bridge River district may in the future be utilized by manufacturers in Canada. For that reason a chemical analysis of the ash is here appended. For purpose of comparison three other analyses are given.

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[1] Geol. Surv., Can., Ann. Rept., vol. XII, p. 21B.
[2] Geol. Surv., Can., Sum. Rept., 1915, pp. 50–61.
[3] Geol. Surv., Can. Ann. Rept., vol. VII, 1894, p. 25C.
[4] Geol. Surv., Can., Ann. Rept., vol. IX, p. 96S.
[5] Geol. Surv., Can., Ann. Rept., vol. XI, p. 10R.
[6] Geol. Surv., Can., Ann. Rept., vol. I, p. 22 M.
[7] Wilson, M. E., Geol. Surv., Can., Memoir 98. (In press.)
[8] Geol. Surv., Can., Ann. Rept., vol. IV, p. 111K.
[9] Geol. Surv., Can., Ann. Rept., 1870–71, p. 237.
[10] Geol. Surv., Can. Sum. Rept., 1916. See report by A. O. Hayes.
[11] Pumice is used as a polishing material, in the manufacture of scouring soap, metal polisher, etc.

Analyses of Siliceous Earth.

	1	2	3	4
SiO_2	63·94	80·40	80·80	76·58
Al_2O_3	16·34	6·30	5·96	16·13
Fe_2O_3	3·57	1·42	1·42	
MgO	1·38	0·46	0·54	0·18
CaO	3·18	0·32	0·36	0·60
Na_2O	8·39 by diff.	not det.	not det.	0·34
K_2O		0·45		0·16
H_2O	2·75	10·00	11·00	5·80
TiO_2	0·45	0·30	0·30	0·25
	100·00	99·65	100·38	100·04

1. White andesitic pumice, Bridge River map-area, Lillooet, B.C.
2. Impure diatomaceous earth (locally known as kaolin), 18 miles from Ashcroft, B.C.
3. Volcanic ash and diatomaceous earth from Deadman river, north of Savona, B.C.
4. Siliceous earth, from Neuberg, Germany, after some preparatory drying and crushing. Analyst, M. F. Connor, Mines Branch.

Diatomaceous or infusorial earth (kieselguhr) is a siliceous deposit formed in lakes and swamps, as well as in the sea, and when pure is composed chiefly of the frustules and fragmentary debris of diatoms. Bedded deposits of this nature accumulate abundantly where siliceous volcanic tuffs are being deposited. Such conditions prevailed during Tertiary time at many localities in the Cordilleran region.

The diatomaceous earth from the Kamloops district is admixed with rhyolitic dust and other detritus, chiefly clay, which lowers its silica content to 80 per cent. The purer varieties of the earth contain from 90 to 97 per cent silica. The British Columbia earth is a soft, white, chalk-like substance of fine texture which frequently has been mistaken in the field for kaolin.

The material is utilized in the manufacture of high explosives in addition to its extensive use as a polishing powder, a steam pipe packing, and as an absorbent for various liquids.

Limestone.

A representative sample of limestone from the Bridge River series of Carboniferous age was taken from Marshall ridge close to the wagon road. The material was analysed in the Mines Branch laboratory with the following result:

SiO_2	Fe_2O_3	Al_2O_3	$CaCO_3$	$MgCO_3$
0·46	0·17	0·23	96·73	1·83

The main belts of limestone outcropping in the map-area are indicated on the outline map accompanying the Summary Report of 1915. Much of this material is suitable for burning and the production of lime.

The lime production for British Columbia during 1914 amounted to 151,689 bushels valued at $56,767, the average price per bushel being 37·4 cents.[1]

[1] McLeish, John, "Mineral production of Canada 1914," Mines Branch, No. 384, p. 343.

Index Molybdenite Mine, Lillooet Mining Division.

The Index molybdenite group of six claims, including the Index, Last Chance, Globe, Iron Crown, C. P. Fraction, and Legal Tender, was located in July, 1915, by J. B. Perkins. During September Perkins sold his interest to A. F. Hautier and the property was acquired the same month by Newton W. Emmens, of Vancouver. Mr. Emmens made an initial shipment of 8 tons 300 pounds in November, 1916, to the International Molybdenum Company, Renfrew, Ontario. The company reports this ore to assay 15·01 per cent molybdenite (MoS_2) and to be quite amenable to treatment. A wagon road, which will follow the valley of Phair creek and reduce the actual haulage of ore to a distance of about 11 miles, is now projected from the mine to the railway at Seton lake. At present the property is reached by wagon road from Lillooet down the west side of the Fraser valley for a distance of 14 miles, thence by pack trail for 13 miles through the canyon of Texas creek and up the north fork of the creek to the high divide between the source of the north fork of Texas creek and that of Phair creek, a tributary of Cayoosh creek. At the time of visit the lower portion of this trail was almost impassable owing to the damage done by the spring freshets in 1916. The owners of the property, however, had built a trail over Antoine mountain which joined the main trail above the canyon. This lengthened the trip by about 3 miles and necessitated a climb over a summit 4,000 feet above the Fraser river.

General Geology. As characteristic of molybdenite ores the world over, the ore in this district is difficult to follow and of an erratic nature. It appears to be confined to certain ill-defined zones near the upper border of a cupola stock of very quartzose granite.[1] This granite mass is roughly oval-shaped in plan and elongated for about one mile in a northeast and southwest direction. The stock, which is intrusive into schists and limestone probably belonging to the Whitecap schist series,[2] appears to be dipping steeply to the west and pitching to the south. Time and inclement weather did not permit of much study of the regional structure. A prominent limestone member forms bold outcrops encircling the ore-bearing stock and the schists are cut by numerous porphyry dykes. Another parallel granite stock occurs a short distance to the east and outcrops along the Texas Creek trail. This stock, however, has been laid bare by erosion to a greater depth than the Index stock, and a coarser grained biotite granite, with streaks of diorite in it, is thus exposed.

Character of Ore. The molybdenite ore is very clean and free from copper, tungsten, tin, bismuth, arsenic, and other deleterious elements. The highest grade ore is 76 per cent molybdenite and occurs sparingly in bunches up to one foot in width, along certain closely spaced joint planes in the fine-grained quartzose members of the granite stock, as well as impregnations in the intervening granite. The low grade ore could be readily concentrated, as the molybdenite occurs in rosettes and flakes that are uniformly distributed throughout the disintegrating granitic gangue. The latter consists of quartz, feldspar, and in places sericite flakes. Biotite mica occurs as an essential constituent in the blocky granite away from the ore zones. Molybdenite occurs less sparingly in rusty, vitreous, quartz veinlets cutting the granite. In the vicinity of the ore, the granite is much stained by the straw-yellow trioxide of molybdenum, molybdite; and this, along with a certain amount of kaolinization of the orthoclase feldspar, serves as a good indicator of the ore zone.

Ore Occurrence and Development. Very little development work had been done on the property up to July 1916, and at that time the best showing was on

[1] Microscopic examinations of the rocks and ores have not yet been made and only field terms are used. 'Cupola stock' is a term introduced by Professor R. A. Daly to indicate a connexion in depth of minor granitic masses with a main underlying batholithic mass.

[2] Geol. Surv., Can., Sum. Rept., 1915, p. 79.

the Cottonwood side of the divide a couple of hundred feet below the summit. The ore there follows a system of closely spaced joints making an angle of 45 degrees with the dominant northeast direction which is parallel to the greatest diameter of the stock. The ore-bearing joint planes at this point strike north 60 degrees east (magnetic) and dip steeply to the southeast to vertical. The foot-wall is rusty, oxidized granite with included kernels of fresh, unoxidized rock and contains occasional flakes of biotite mica. The mica becomes more abundant away from the ore zone, where the normal granite is traversed by master joint planes striking north 15 degrees east (magnetic) and dipping steeply to the east or vertical. The hanging-wall is composed of very quartzose granite. The strike of the master joint planes varies a great deal from place to place and it might be advisable to make a detailed study of the various systems and their relations to the borders of the mass. In the short time available in the field, several different systems were recorded and plotted. In the southerly ore zone, with one exception, the longitudinal sets appear to terminate the more favourable transverse sets. The transverse sets in places are so closely spaced and altered as to approach shear zones in character although they did not appear to be persistent enough to classify them as such. On the summit above the main showing, another outcrop of ore follows an east and west (magnetic) set of joint planes, dipping steeply (70 degrees) to the north and in close proximity to veinlets of vitreous quartz. Farther to the north, the molybdenite appears to be confined to rusty vitreous quartz veinlets which may represent the feeders to the main deposit. The granite contains brown rusty spots near the ore. At this northern locality, both walls are composed of the same fine-grained granite, containing the kaolinized orthoclase feldspar and a little biotite. Much broken-up granite and float of molybdenite and molybdite lie on the surface between the showings, as at this altitude (about 8,000 feet) mechanical disintegration of the rocks proceeds very rapidly and no doubt rich ore zones have already been eroded away. There is at present considerable ore in the scattered, loose, surface blocks of granite. Farther to the south, toward the border of the mass and at the same elevation as the main showing, some 5 to 8 per cent ore was found following a series of platy joint planes which strike north 50 degrees west and dip to the southwest at an angle of 41 degrees. Near the contacts the master joint planes dip at lower angles and are at right angles to the other sets of joint planes.

The most northerly occurrence of molybdenite visited was several thousand feet along the summit from the main deposit and 3 feet from a vesicular and amygdaloidal, lamprophyre dyke. The amygdules are of chalcedonic quartz and calcite. This dyke is crooked but has a general north and south trend and an easterly dip of about 50 degrees. The master joint planes on the west side of the dyke are unmineralized and strike north 30 degrees west and dip from 86 degrees south to vertical. On the east side of the dyke, the master joint planes strike parallel to the dyke which at this point, near the molybdenite cropping and gouge material, strikes north 45 degrees east and dips southeasterly into the hill at an angle of 52 degrees.

Future Work. In laying out development work, close attention should be paid to the various systems of jointing in the granite stock near the ore zones. The belts of blocky biotite granite, traversed by regular jointing parallel to the contact, should be avoided, whereas the closely spaced sets of joint planes transverse to the contacts and those zones of fine-grained, quartzose granite penetrated by vitreous quartz veinlets and in places silicified and kaolinized, should be carefully prospected for ore. At the present stage of development the open-cut and quarry method of mining would appear to be the safest and best system. The various occurrences should be thoroughly tested for permanence and con-

nected up before tackling underground development. Much broken-up granite and float lie on the surface and make it difficult to trace the ore between outcrops. Should the short season, when this high rocky summit is free from snow and ice, prevent this surface work, it might be advisable to tunnel in on the main showing a couple of hundred feet below the summit, keeping with the ore, and to drive in toward the neighbouring occurrences. Both walls should always be tested for parallel ore bunches along joint planes, and for intervening milling ore. It is to be expected that in this pneumatolytic type of deposit[1] (stock work) much blocky unproductive granite will be encountered between the various ore zones. For this reason it would be well to obtain all the surface data possible regarding position of ore zones, joint systems, variations in composition of granite, etc., and have all the information assembled and plotted on one plan before undertaking extensive underground development.

Slocan Area, Ainsworth and Slocan Mining Divisions.[2]

Economic Geology. Owing to the present high price of metals, mining and prospecting in the Slocan silver-lead-zinc district is being energetically carried on. Since discovery in 1891, the district has produced metals to the value of approximately $40,000,000.

During the course of the field work, over twenty working mines and as many prospects were visited. The main vein fissures, which generally correspond in strike and dip with the master joint planes, are shown on the accompanying outline map as well as a few of the more important replacement veins. The replacement veins in contrast to the fissure veins, carry low values in silver and lead and high values in zinc. They also strike and dip with the replaced formation which is invariably limestone. The map and structure sections further indicate the location of the most productive metalliferous belts within the closely folded roof rocks of the batholith[3] as well as their position with respect to the granitic intrusions and main contacts. Considerable faulting along certain axes of folding and offsetting of vein fissures and master joint planes along bedding planes have taken place both before and after mineralization. The faulting and fracturing are systematic and indicative of the nature of the torsional and compressional crustal stresses set up during late Jurassic time along this northern margin of the Nelson batholith. What appears to be a down-faulted block or graben of Slocan series between the Kootenay Lake and Slocan Lake horsts[4] of the Ainsworth (Shuswap) series, has been upbowed in the middle by the Nelson batholith forming thus a local anticlinorium[5] (see structure section A–B). As a result of differential movements both horizontally and vertically consequent upon batholithic invasion and crustal readjustment in this broad belt of much folded and crushed Slocan series, a great variety of vein deposits have been formed. All transitions from true fissure veins with well-defined walls, to fissure zones made up of a series of interrupted torsional or crevasse-like fissures in line or *en échelon*, exist. The fissure veins and zones may pass into stock works or a series of connected veins between the hanging and foot-wall fissures. The ore shoots and pockets occur frequently where a formational slip or fault intersects the vein fissure or mineralized master joint plane. Where the country rock is massive

[1] "Notes on the geology of the Molly molybdenite mine, Lost creek, Nelson mining division, B.C.", Trans. Can. Min. Inst., 1915, pp. 247–255.
[2] For preliminary reports by O. E. LeRoy on geology and ore deposits of the Slocan district, see Geol. Surv., Can., Sum. Rept. 1908, pp. 67–68; 1909, pp. 131–133; 1910, pp. 123–128; 1915, p. 93.
[3] Batholith means the largest kind of intrusion of molten rock, generally granitic and characteristically found in great mountain ranges.
[4] The direct opposite of graben or trough, a horst is an upfaulted block bounded by diverging downward fault planes.
[5] Anticlinorium means a broad anticlinal belt or composite anticline compounded of minorf olds whose axes in this case converge downwards, or in other words a bowed-up mass of folds.

and tight, the angle between the vein fissure or master joint plane and the bedding plane, along which the shifting movement took place, is apt to be nearly a right angle and an ore pocket, if present at such intersection, is small, though rich. On the contrary, if the country rock is crushed and loose the vein fissure is, as a rule, undulating and makes acute angled intersections with the formational slips or cross fissures. The intersections are in this case more favourable for the localization of workable ore shoots.

General Geology. The main problem in the field work of 1916 was to determine the structural relations of the Selkirk, Niskonlith, Shuswap, and Slocan series and correlate them with similar formations in East Kootenay. The key to the regional structure was found to the north of the Slocan map-area at the heads of Davis and Cooper creeks in the southern Lardeau mountains.

Fossils were found near the base of the Niskonlith series as mapped on the West Kootenay sheet[1], on both limbs of a compressed syncline known as the Milford syncline (F_1 and F_2 on section A–B). This syncline is bounded on the west by an anticlinal belt of Selkirk series (now named the Kaslo volcanic group) and on the east by a reverse fault which upthrusts as a horst the Shuswap or Ainsworth series into juxtaposition with the eastern limb of the Milford syncline and locally with the underlying Kaslo schists (see section A–B). A plane-table traverse plotted on the scale of 400 feet to 1 inch was run across the syncline from the Kaslo schists eastward to the Ainsworth series. This detailed survey of the lithological members, their sequence, and dips undoubtedly proves the synclinally folded nature of the sedimentary series at this locality. Traced southward the Milford syncline becomes more compressed and overthrust to the east and on that account the structure might be determined erroneously as monoclinal. Northward in the Lardeau mountains this synclinal belt widens and appears to be intruded by granitic masses.

Eight new fossil localities were discovered during the past season in the main belt of Slocan series southwest of the Kaslo schist anticline. The fossils and the lithology of the series on both sides of the anticline are similar. The fossil localities are indicated on the accompanying outline map. E. M. Kindle submits the following preliminary report on the collection: "Lots S. F. 57 to S. F. 90 (F_3–F_6)[2] from the district east of Slocan lake show numerous fragmentary specimens of fossils in dark schistose, limy material. Sections of crinoid stems are present in great numbers. A few detached crinoid plates and imperfect sections of gasteropods comprise the only other fossil remains that can with any degree of certainty be referred to any order or group of fossils. It is accordingly impossible to use this material for correlation except in the broadest way. The material, however, plainly indicates a post-Cambrian age for the beds represented. The beds are probably of middle or upper Palæozoic age. The fossils alone do not warrant a more definite correlation for the fauna."

"Lots S. F. 1 to S. F. 56 (F_1–F_2)[2] are in fragmentary character very similar to those just mentioned. In addition to numerous crinoid stems they show two gasteropods and a small coarsely ribbed fossil fragment of undetermined affinities. One of the gasteropods though preserved only in section is sufficiently preserved to leave little doubt that it represents a species of *Raphistoma*. On the evidence of this specimen, the horizon is provisionally determined as Ordovician. It may be noted that the numerous sections of crinoid or cystid columns, which at first glance incline one to surmise a Carboniferous horizon for the fauna, are much smaller than those most commonly met with in the Carboniferous. A diameter of 1 or 2 mm. represents the average size of these columns."

[1] Geol. Surv., Can., 1904. Map No. 792. Here the Niskonlith is really an isolated infold of the Slocan series.
[2] See map 1667.

General Notes on Stratigraphy and Correlation of Kootenay Terranes.[1]

INTRODUCTION.

During the 1916 field season the rocks of the Purcell, Summit, Selkirk, and Niskonlith series in the Kootenay district were examined over an extended area and the various structural units traced across Kootenay lake and river (Purcell trench) into the Selkirk system of mountains. The opportunity of doing this was afforded through the necessity of taking the Geological Survey pack train of five horses stationed on St. Mary prairie to the Slocan district for use there in transporting camp supplies and equipment to conveniently situated mountain camps. As a result of this reconnaissance traverse it was possible to make the necessary correlations between the formations outcropping in the Slocan and Cranbrook map-areas respectively.

The Survey party started out on the overland trip from Marysville to Kaslo on July 28, travelling by way of St. Mary lake, up Meachem and Fiddler creeks to the Evans Mountain divide and thence down Goat river to the towns of Kitchener and Creston. The Kootenay river was crossed at Creston August 6. From the mouth of Summit creek the old Dewdney trail was followed up to and over the Nelson Range divide, then down Lost creek to the Molly mine from which point a good wagon road leads to Salmo and Ymir, towns in the valley of Salmon river. From Ymir it was necessary to follow the railway, the party arriving in Nelson August 13. Owing to the poor condition of the trail around Kokanee lake and down Mansfield (South Fork Kaslo) creek the remainder of the trip was made by boat, Kaslo being reached on August 14.

The following general notes taken on the trip across the ranges are here recorded in the hope that although fragmental they may assist in the solution of the broader regional problems bearing upon the stratigraphy and structure of the oldest rock terranes in British Columbia. The notes are illustrated by structure sections (Map 1666) and a suggested correlation table presented for critical examination and field tests. This preliminary statement is only tentative, pending further field work.

With the steady accumulation of geological field data bearing on this subject, it is hoped that in the near future the Kootenay district will yield critical evidence sufficiently convincing to narrow down the various alternatives so prevalent at present to a single tenable correlation table which will be in harmony with all the field facts and stand the test of time.

SADDLEBACK MOUNTAIN FOSSIL LOCALITY IN PURCELL SERIES.

Obscure fossils were discovered near the top of the Aldridge member of the Purcell series on the high rocky divide between the headwaters of Meachem (Whitefish) creek and the East Fork of Goat river. They were found at an altitude of 8,151 feet above sea-level in argillaceous beds on the eastern slope of Saddleback mountain. L. D. Burling, of the palæontological division of the Geological Survey, reports on them as follows:

"The horizon of these fossils is given as probably Aldridge, but it was mapped by the earlier observers as Kitchener; both of these units are of Pre-Cambrian age.

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[1] See the following references:
Daly, R. A., Geol. Surv., Can., Mem. 38, 1912, pp. 161–205.
—Geol. Surv., Can., Mem. 68, 1915, pp. 87–97.
Schofield, S. J., Geol. Surv., Can., Mem. 76, 1915, pp. 41–51.
—Geol. Surv., Can., Mus. Bull. No. 2, 1914, pp. 1–13.
—Geol. Surv., Can., Sum. Rept., 1914, p. 41.
Burling, L. D., Geol. Surv., Can., Mus. Bull. No. 2, 1914, pp. 1–37.

Specimen SB1 (and less characteristically SB2 and SB9) appears to represent a specimen of Beltina, the crustacean-like remains which have been decribed from the Greyson shales in central Montana,[1] and the Altyn limestone of northern Montana[2] and southern Alberta.[3] Specimens SB3, 4, 5, 6, 7, 8, and 10 all appear to be from the same horizon and, while they contain variously shaped, pebbly material, this does not appear to be organic. Specimen SB11 bears darker mottlings but these are unrecognizable and are not believed to be organic."

The section consists of a conformable series of rapidly alternating beds of light grey quartzite, sun-cracked in places, massive and thinly-bedded argillites, cross-bedded sandstones, greenish grey schists containing quartz veinlets, phyllites and a few impure limestone beds. The series is cut here and there by rusty weathering granite porphyry dykes.

The Saddleback series, as exposed on this rocky east-west ridge transverse to the regional trend of the formations, forms a part of the southwestern limb of a great anticlinal dome elongated in a general north and south direction and including many minor open folds. The core of the dome is composed of the Aldridge or basal member of the Purcell series which has been deeply incised by St. Mary river. The fossiliferous horizon is near the top of the Aldridge where it passes gradationally into the overlying Creston. The beds at this locality have southwesterly dips and plunge under the massive white quartzites of the Creston formation. No evidence of graben or trough faulting was noted as indicated on the Cranbrook map which shows a block of Kitchener down faulted into juxtaposition with Aldridge to the north and Creston to the south. On the contrary the stratigraphy and structure at this western border of the map-area appear to be remarkably regular and undisturbed by profound breaks.

Glacial striæ were noted at several places on the ridge, the highest markings being at an altitude slightly exceeding 7,000 feet above sea-level. The average trend of the striæ is north 66 degrees west.

ALDRIDGE CONGLOMERATE IN VALLEY OF GOAT RIVER.

About 5 miles south of the fossil locality the rusty weathering Aldridge formations plunge under an east-west trending synclinal basin of light greyish quartzites of the Creston which is exposed for a width of several miles in the valley of Goat river. This belt of Creston forms the bold mountain massifs to the east, culminating in Grassy mountain (elevation 8,075 feet). Westward the folded formations have been locally upbowed to conform to an intrusive arm of granite from the nearby Nelson batholith. This tectonic basin of Creston separates the St. Mary anticlinal dome from a similar dome farther south which is deeply entrenched by Goat river above the town of Kitchener. Near what appears to be the core of this latter dome of Aldridge there is exposed in a brûlé a conglomerate formation, which may prove on further investigation to be the true base of the Purcell series resting unconformably upon a small island of Archæan schist of the Shuswap series. The locality is on the western slope of the valley, 350 feet above the river, at a point about 6 miles below the main forks and 18 miles south of the pass near the headwaters of Meachem and Fiddler creeks.

The conglomerate is a quartzose and massive variety composed of a heterogeneous assemblage of angular to subangular pebbles, up to 2 inches in diameter, of grey and white quartzite and vitreous quartz in a matrix of quartz sand which shimmers in the sunshine. A very small proportion of the pebbles are well

[1] Walcott, C. D., Bull. Geol. Soc. Amer., vol. X, 1899, pp. 237–239.
[2] Willis, Bailey, Bull. Geol. Soc. Amer., vol. XIII, 1902, p. 317.
[3] Daly, R. A., Geol. Surv., Can., Mem. No. 38, 1912, p. 65.

rounded. Arkosic grits, so common in the basal members of the Summit series, are absent, and there is no lithological resemblance between this Aldridge conglomerate and the Irene conglomerate of the Summit series. The basal beds are wash covered at this locality so that it is impossible to see the floor upon which the conglomerate rests. The conglomerate where exposed, is cut by veinlets of quartz which here and there appear as quartz-filled torsion cracks lying perpendicular to the bedding planes. Conformably above the conglomerate is a brownish to buff weathering sedimentary series of sand, mud, and lime beds now metamorphosed to contorted schists, in part platy and thinly bedded, with layers up to one foot thick of alternating quartzite and impure limestone.

The formational strike is north and south; the dip varies from 60 degrees near the base of the section to less than 20 degrees toward the top. The east-west trending, minor folds in the upper portion of the section have wider amplitude and are more open than the corresponding folds toward the centre of the dome. The formations display pronounced planes of cleavage or schistosity which so far as observed intersect the bedding planes both in strike and dip at varying angles, depending upon the position of the beds with respect to the axis of the dome. At an elevation of 530 feet above the conglomerate outcrop, the angle between the dip of the quartzite beds and that of the planes of schistosity is 30 degrees; the bedding planes strike north and south and dip at an angle of 40 degrees to the west, whereas the planes of schistosity strike at a small angle west of north and dip 70 degrees westward. It is inferred, therefore, that the centre of the dome is to the southeast. At an elevation 200 feet higher, massive grey quartzites become more prominent in the rusty weathering series and the distant summit of the ridge appears to be composed of the overlying Creston member of the Purcell series.

Farther south, along the lower stretches of Goat River valley, extensive sills of hornblende gabbro form prominent cliff exposures similar to those of the St. Mary dome. They represent the intrusive equivalents of the Purcell lavas outpoured in Siyeh or probably early Cambrian time.

PRIEST RIVER TERRANE AND SUMMIT SERIES.

On the West Kootenay map sheet[1] the Purcell series and Priest River terrane of Daly are indicated by McConnell and Brock as one and the same series, namely the Selkirk (Upper ?); and Daly's Summit series is coloured as Lower Selkirk, the whole Selkirk series being provisionally referred to the Cambrian or Cambro-Silurian. On the same map the Pend-d'Oreille group of Daly is coloured Niskonlith and referred to the Lower Cambrian. In the explanatory notes to the map Brock states: "This subdivision into Selkirk and Niskonlith series has been made on purely lithological grounds and upon resemblances to rocks along the main line of the Canadian Pacific railway as worked out by Dawson and McConnell. It is possible that the section in the map-sheet has been reversed and that the chronological sequence of the rocks here called Upper and Lower Selkirk and Niskonlith, is the opposite of that given. The fact that old-looking eruptions were found in the Upper Selkirk series that were not observed in the other two series lends colour to such a view. But in the absence of more detailed work to determine this point the above nomenclature and correlation is provisionally adopted."

The regional work of the past field season in the Kootenays, in which fossils were found for the first time in both the Purcell and Niskonlith series, has conclusively proved that the chronological sequence as shown on the map *is* reversed. The same may hold true for Dawson's similar section farther north in the Shuswap

[1] Geol. Surv., Can., 1904, map No. 792.

Canada
Department of Mines
GEOLOGICAL SURVEY
Issued 1917
SLOCAN LAKE
SILVER RIDGE
IDAHO PEAK
PAYNE RIDGE
Structure section along line AB
Extension of section AB in same direction to Southern Lardeau Mountains
KOOTENAY LAKE
Structure section along line CD
LEGEND
Symbols
Geological boundary
Aerial tramway
Wagon road
Trail
M^c CARPENTER
Kaslo
MARBLE QUARRIES
Longitude West from Greenwich
Catalogue No. 1667
SLOCAN MINING AREA, KOOTENAY DISTRICT, BRITISH COLUMBIA
Scale of Miles
To accompany Summary Report by C.W. Drysdale, 1916
Drainage and part of culture from Slocan topographical map 1909 B; geology by O.E. LeRoy 1909-10 and C.W. Drysdale 1916

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Correlation sections showing structure of Kootenay Terranes, British Columbia

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Lakes region where Daly[1] has recently thrown the Niskonlith and Adams Lake series into the Archæan Shuswap terrane, correlating both with his Priest River terrane at the International Boundary. At Albert canyon, however, Daly has thrown the Niskonlith of Dawson's Selkirk section into the Beltian. Future investigation may prove that both the Adams Lake and Niskonlith series of the Shuswap and Albert Canyon regions are a closely folded and faulted series of Cambrian and post-Cambrian age similar in lithology and chronological sequence to the southern Kootenay sections which have been mapped in more detail.

Recent field work in the Kootenays has forced the writer to differ from Daly in several important conclusions:

(1) The Priest River terrane, instead of being Archæan, is considered to be Beltian and simply the hydrothermally metamorphosed extension of the Purcell series across the Purcell trench as originally shown on the West Kootenay map. The metamorphism is due to batholithic invasion which in this locality appears to conform closely to the regional structure, the formations swinging to parallel the granite contacts. The terrane includes the folded and domed Kitchener, Creston, and Aldridge members of the Purcell series cut, here and there, by granite and complementary dykes from the large adjacent masses of granite.

(2) In the Purcell trench no evidence was found of a pronounced regional break or meridianal fault with a downthrow which "may measure 20,000 to 30,000 feet."[2] Daly assumes and indicates on the map such a fault which separates his Priest River terrane from his Kitchener (Aldridge of Schofield) east of the hypothetical fault.

(3) The Irene conglomerate is not considered to be the base of the Belt terrane in Canada but simply the base of a younger series than the Purcell of probably Lower Cambrian age. It may prove to be the western equivalent of the Bow River and Siyeh (?) conglomerates east of the axis of uplift.

(4) The Irene volcanic formation is provisionally correlated with the Purcell lava in the Siyeh and may be used roughly as a horizon marker. The members of the Purcell series below the Siyeh represent the true Pre-Cambrian sediments of the Belt terrane in Canada; the members above the Siyeh and below the Burton the eastern equivalents of the Summit series.

(5) The structure of the Summit series, instead of being monoclinal, is considered to be rather a series of folds with a tendency to overturn and in places to form overthrust faults to the east. The major syncline on the transverse ridge north of Lost creek is of similar magnitude to Daly's Selkirk Summit syncline on the main line of the Canadian Pacific railway near Glacier. This syncline brings about a repetition of beds and no evidence was found of a thrust fault and rotation of beds as inferred by Daly.[3] The writer's interpretation of the structure in the field is shown in the accompanying structure section (Map 1666).

(6) The members of the Summit series as well as the Kitchener, Creston, and Aldridge members of the Purcell series derived their sediments in large part from the same source, namely, the Shuswap terrane. They, therefore, possess many lithological resemblances in common, a fact which would readily lead to wrong correlations particularly where fossil evidence is lacking. The basal conglomerate and grits of the Summit series, however, contain pebbles of the underlying Kitchener, Creston, and Aldridge members of the Purcell series.

(7) A hiatus is represented in the contact between the Summit or Selkirk series (Lower Cambrian (?)) and the Niskonlith and Slocan series (post-Cambrian) in the Rocky Mountain geosynclinal. In fact all four terranes

[1] Geol. Surv., Can., Mem. 68, 1915, pp. 10–55.
[2] Geol. Surv., Can., Mem. 38, 1912, p. 277.
[3] Geol. Surv., Can., Mem. 38, 1912, pp. 278–279, Fig. 18, map 80A.

represented in the Kootenays, namely the Shuswap, Belt, Cambrian, and post-Cambrian respectively, are distinct sedimentary units separated by well-defined breaks and unconformities.

ECONOMIC BEARING OF REGIONAL GEOLOGY.

To those interested in the development of the mineral resources of the Kootenays, the district may be divided naturally into definite metallographic belts named according to the chief metal found within them. Prospectors and miners have already to a certain extent so divided the region, the best known divisions being the gold, silver-lead-zinc, and copper belts repectively. Such metalliferous belts may be traced with few breaks from the southern to the northern boundaries of the Kootenay district and offer a fertile field for prospectors. It so happens that the trend and areal extent of the different belts correspond exactly with those of the several rock terranes under discussion. The economic bearing of the regional geology, therefore, is apparent and a general knowledge of it is invaluable to the prospector in his search for ore.

The main metallographic belts so far developed in the Kooetnays may be tabulated as follows:

Kootenay Metallographic Belts.

Metallographic belt.	Main type of deposit.[1]	Rock terrane and formation.
Silver-lead-zinc	Fissure veins	Post-Cambrian terrane (Slocan, Niskonlith, and Pend-d'Oreille series).
	Replacement (blanket) veins	Pre-Cambrian terranes (Purcell and Ainsworth series).
Gold quartz and antimony (Kaslo schist)	Fissure veins	Lower Cambrian terrane (Summit, Lower Selkirk, and Kaslo schist series)
Copper-gold	Differentiates and veins	Purcell sills of hornblende gabbro (Lower Cambrian ?)
	Replacement lodes	Rossland volcanic group (Triassic (?) terrane).
Molybdenite and tungsten	Stockworks and pegmatite veins	Post-lower Jurassic terrane (Nelson granite stocks).

It must be borne in mind that the ore deposits in the various metallographic belts are confined to certain ore zones which, with the possible exception of replacement deposits, strike in an easterly or northeasterly direction transverse to the general northerly trend of the formations. The exact positions of the ore zones in the belts depend upon many different geological factors chief of which is the nature of the crustal stresses set up in the broad zones marginal to the granite batholiths at the time of consolidation, as well as the physical and chemical character of the roof rocks penetrated. The most favourable areas to prospect are those portions of the roof intruded by cupola stocks and porphyry dykes. Such satellitic intrusions from the batholith probably paved the way for the ascent of later hot mineral solutions and vapours which came from the same

[1] For a classification of British Columbia ore shoots and criteria for their recognition see Geol. Surv. Can., Mem. 94, 1917, p. 62.

PRELIMINARY CORRELATION TABLE FOR KOOTENAY TERRANES, B.C.

EPOCH	SELKIRK RANGE, SOUTHWEST KOOTENAY	SELKIRK RANGE, NORTHWEST KOOTENAY	PURCELL RANGE, SOUTH CENTRAL KOOTENAY	ROCKY MOUNTAIN RANGE, NORTHEAST KOOTENAY AND ALBERTA	ROCKY MOUNTAIN RANGE, SOUTHEAST KOOTENAY AND ALBERTA[1]	COEUR D'ALENE DISTRICT, IDAHO.[2]	PHILIPSBURG DISTRICT, MONTANA[3]
CARBONIFEROUS TO ORDOVICIAN	Slocan, Pend-d'Oreille, and Niskonlith series, chiefly argillaceous and calcareous	Laurie argillite and limestone of Daly's Albert Canyon division ("Niskonlith series' of Dawson)	Jefferson limestone (Devonian)	Halysites beds (Silurian) Graptolite shales, Goodsir shales } (Ordovician)			Quadrant quartzite Madison limestone Jefferson limestone Maywood limestone and shale
UPPER CAMBRIAN				Castle Mountain group: Ottertail limestone Chancellor argillite Sherbrooke limestone Paget " Bosworth "			
MIDDLE CAMBRIAN			Elko limestone Burton shale and sandstone	Castle Mountain group: Eldon limestone Stephen " Cathedral " Mount Whyte metargillite			
LOWER CAMBRIAN	Summit series (Daly): Ripple and Beehive quartzites and metargillites	Sir Donald quartzites and grit	Roosville quartzite	St. Piran quartzite		Striped Peak shales and sandstones	Red Lion limestone Hasmark dolomite Silver Hill calcareous shales Flathead quartzite and conglomerate
	Summit series (Daly): Dewdney, Monk, and Wolf quartz grits and quartzites	Ross quartzite, grits and metargillites	Galton series: Phillips metargillite Gateway sandstone	Bow River series: Lake Louise metargillite	Kintla metargillite Sheppard quartzite and dolomite		
	Summit series (Daly): Irene volcanics, limestone, and conglomerate	Basaltic lava, Nakimu limestone, and Cougar conglomerate	Purcell lava Siyeh limestone and conglomerate	Fairview conglomerate and coarse sandstone	Siyeh limestone and Purcell lava		
BELTIAN	Priest River terrane (Daly): Kitchener		Purcell series: Kitchener	Hector metargillite Corral quartzite and sandstone	Grinnell and Wigwam	Wallace	Greyson shale Newland calcareous argillite
	Creston grey quartzite	Cougar quartzite	Creston grey quartzite		Appekunny and McDonald and Hefty	St. Regis, Revett, and Burke quartzites	Ravalli quartzite
	Aldridge: Upper Lower	Illecillewaet Moose Basal quartzite	Aldridge rusty weathering quartzites		Altyn siliceous dolomite Waterton dolomite	Prichard metargillite	Prichard metargillite Neihart quartzite
PRE-BELTIAN OR ARCHÆAN	Shuswap quartz-mica schist series	Shuswap orthogneisses chiefly					

[1] Allan, J. A., Geol. Surv., Can., Mem. 55, 1914, p. 60.
[2] Calkins, F. C., U. S. Geol. Surv., Prof. Paper No. 62, 1908.
[3] Calkins, F. C., U. S. Geol. Surv., Prof. Paper No. 78, 1913, pp. 32–34.

deep-seated source and which in turn circulated through faults and fissures formed as a result of crustal readjustments following batholithic intrusion. The ore shoots were deposited at certain geologically favourable localities in the vein fissures.

Replacement (blanket) veins occur in isolated cases well up in the sedimentary roof where there is no direct evidence of the proximity of granitic intrusions; and a few rich fissure veins have been mined well within extensive granite masses, as a rule, in close association with lamprophyre dykes. The deeply eroded portions of batholiths, however, and the rock formations very far remote from granitic intrusions are seldom productive.

A certain amount of overlapping of metallographic belts is bound to take place toward the borders of the belts, as for example in the Ymir mining camp where the silver-lead (Pend-d'Oreille series) and gold quartz (Summit series) belts are in contact and the galena ore carries high values in gold.

RECONNAISSANCE OF UPPER ELK VALLEY COAL BASIN, BRITISH COLUMBIA.

(*Bruce Rose.*)

Three weeks in September were spent in a preliminary examination of the coal areas of Upper Elk valley, British Columbia. Elk river lies just west of the continental divide in the Rocky mountains. Its source is in the Elk lakes $3\frac{1}{2}$ miles north of 50 degrees 30 minutes north latitude. From there it flows south a distance of 84 miles, then turns rather abruptly to the west, cuts across the western Rocky mountains, and joins Kootenay river.

The mountains are disposed in ridges corresponding to the axes of parallel fault blocks with a general north-south alignment. Elk river through the greater part of its course runs in a trough of Cretaceous rocks between high ranges of Palæozoic limestones. On the west, the limestones have been faulted upwards and eastward over the area now occupied by the valley. On the east the Cretaceous rocks of the valley overlie conformably the westward dipping rocks of another large fault block which forms the continental divide. The thrust of the western fault block has tilted the rocks adjacent to it on the east upward until they dip to the east or in places are overturned and in the syncline of Cretaceous rocks thus formed, the river has eroded its valley. In places minor faults and folds break the regular arrangement of the rocks but they are not of a magnitude to detract from the main synclinal structure. The limestone mountains on either side rise to elevations from 4,000 to 5,000 feet above the level of the valley bottom.

This part of Elk valley is one of the best examples of a longitudinal valley in the Rocky mountains. It has developed subsequent to the formation of the mountains. Its course parallels the north-south alignment of the main structural features and has been controlled by them. In contrast to this longitudinal type, many of the valleys of the Rocky mountains cut through the mountain ridges. These transverse valleys antedate the formation of the mountains and have been able to maintain their courses by excavating their valleys as fast as the mountain barriers rose.

Upper Elk valley extends roughly from the junction of Elk and Fording rivers, 8 miles south of 50 degrees north latitude, to its head. Fording river, a tributary of the Elk from the east, runs southward in the same Cretaceous trough as the Elk. It parallels the Elk at a distance of from 3 to 5 miles for 30 miles and is separated from it by a ridge of mountains, the Green Hills, which rise in places 3,000 feet above Elk valley.

At the junction of Fording and Elk rivers the coal-bearing rocks have been completely removed by erosion and the valley bottom for several miles is occupied by the shales and sandstones which at other places separate the coal-bearing series from the Palæozoic limestones. To the south is the Crowsnest coal-field which forms part of the same syncline as Upper Elk Valley basin. The Crowsnest coal-field has been described by McEvoy[1] and by Leach.[2]

The coal of Upper Elk valley is similar to that of the Crowsnest coal-field, mined at Michel and Fernie. It is bituminous and is in general a good steam and coking coal. It occurs interbedded with sandstone and shales and the series as a whole is referred to the Kootenay formation. The thickness of the formation in the Green Hills is approximately 3,500 feet. This is much greater than that reported for the same formation in other areas, but coal seams occur at intervals throughout the series and the conglomerate which separates the formation from the overlying formation in other areas was not seen here. Between the rocks of the Kootenay formation and the Palæozoic limestones there is a series of shales, sandstones, and calcareous beds which are referred to the Fernie formation (Jurassic), on account of their similar stratigraphic position and lithologic characteristics to the rocks of the Fernie formation in the Crowsnest district.

The following descriptions briefly set forth the information obtained concerning the coal. On ascending Elk valley the first coal seen is in the Green Hills about 8 miles north of 50 degrees north latitude. The Green Hills ridge here rises 3,000 feet above the valley of the Elk. The first 1,500 feet is tree and soil covered, but above this shales, sandstones, and coal outcrop to the top of the ridge. The strata dip 35 degrees east, being on the west arm of the main syncline. Several coal seams of workable thickness outcrop. A section measured here by Leach shows 89·5 feet of coal in twelve seams.[3] The rocks strike with the trend of the ridge and can be seen outcropping for several miles to the north. Lying between Green Hills ridge and Fording river are some lower hills of Palæozoic limestone at the north end of the Wisukitshak range, a spur from the main range of the Rocky mountains. The structural relations of this limestone with the Kootenay rocks is not definitely known but it appears that the main syncline of Elk valley is broken by a hinge fault which dies out to the north and the limestone has been forced up east of the Green Hills ridge. East of the limestone the Kootenay rocks appear again in a minor syncline which unites with the main syncline to the north.

The next coal outcrops seen are about 7 miles farther north at what is locally known as Canadian Pacific Railway headquarters camp. Two coal seams, 10 and 15 feet in thickness, separated by 125 feet of sandstones and shales, outcrop on the west slope of the Green Hills just east of the wagon road, and prospect tunnels have been driven on them. The rocks dip 20 degrees northeast and are like those farther south on the west arm of the main syncline.

For the next few miles to the north no coal outcrops were seen. The valley gradually cuts across the trough of the main syncline at the north end of Green Hills ridge and at Aldridge creek, a tributary from the east, another ridge of hills formed of the rocks of the east arm of the syncline is met. This ridge connects with the hills on the east side of the Fording farther south and to the north dies out in about 6 miles.

Where Aldridge creek cuts across the strata a number of coal seams are exposed and prospect tunnels have been driven on six seams. Owing to the caved condition of the workings exact widths of seams were not obtained, but the combined thickness of the six seams is not less than 50 feet. One seam is at least

[1] McEvoy, Jas., Geol. Surv., Can., Sum. Rept., 1900, pp. 85–95.
[2] Leach, W. W., Geol. Surv., Can., Sum. Rept., 1901, pp. 69–81.
[3] Leach, W. W., Geol. Surv., Can., Sum. Rept., 1901, p. 71.

15 feet thick. The strata dip 35 to 50 degrees west and can be seen outcropping on the ridges north and south of Aldridge creek to heights of at least 2,000 feet.

Two and one-half miles north of Aldridge creek at what is known as Weary Creek camp a tunnel has been driven across the same measures and is reported to cross seven workable coal seams with an average width of 9 feet. One seam at the surface shows 15 feet of coal. The strata here dip 45 degrees west.

Opposite Weary Creek camp on the west side of the Elk river the coal measures are well exposed on Bleasdell creek. The rocks, here on the west arm of the main syncline, have been overturned and dip 55 to 70 degrees west. About twenty seams of coal, varying in width from a few inches to 30 feet, are exposed. Several of these are of workable thickness. They can be seen only in the gorge of Bleasdell creek and cannot be traced on the wooded ridges to the north or south.

North of Weary creek the valley narrows and for the last 12 miles before the summit is reached the limestone mountains rise steeply on both sides. The valley bottom is occupied by forest and swamps and very few outcrops of the Cretaceous rocks occur. A very thick coal seam was reported to occur along the river 5½ miles north of Weary creek, but was not seen. At the summit the valley has lost its synclinal structure. The Cretaceous rocks have not been upturned where the Palæozoic rocks have been faulted over them to the west. The structural valley, however, continues northward and is occupied beyond the summit by the headwaters of Kananaskis river, a northward flowing stream. Just north of the divide an 11-foot seam of coal is reported by Dowling.[1]

On ascending Fording river the first coal seen is at Ewin creek, a tributary from the east 12½ miles north of the junction of Fording and Elk rivers. Here on the south side of Ewin creek the Imperial Coal and Coke Company has driven tunnels on six coal seams, three of which are more than 10 feet thick. Prospect pits on the hills about indicate several more seams. These seams lie on the east arm of the syncline between the north end of the Wisukitshak range and the main range of the Rocky mountains. They were not followed southward, but to the north they follow the ridge east of the Fording for 13 miles, then cross the Fording about one mile north of Henretta creek and connect with the coal on Aldridge creek, previously described. Prospect tunnels have been driven on three seams where they cross Fording river, but were so badly caved that thicknesses could not be measured.

These observations were made during a hurried trip through the valley. There were no prospectors in the field from whom guiding information could have been obtained and most of the time was spent along the main trails and about the easily reached prospects. It is felt that for this reason the information fails to give a true estimate of the importance of the coal field or the probable amount of coal reserve. It has been shown, however, that practically the whole of Upper Elk valley is occupied by a coal basin and that the thickness of workable coal is large. An estimate made from statements of the thickness of seams supplied by private companies places the probable coal reserve at 12,941,000,000 metric tons.[2] This estimate is based on the reserve in 134 square miles and on aggregate thicknesses of coal seams ranging from 6 to 182 feet.

The mining of this coal will be accompanied by no serious difficulties. The methods employed on the pitching seams of the Crowsnest district can be applied here. The valleys of Elk and Fording rivers offer easy routes for railways and connexions can be made with the Canadian Pacific and Great Northern railways at Michel or with the main line of the Canadian Pacific railway to the north.

[1] Dowling, D. B., Geol. Surv., Can., Sum. Rept., 1905, p. 61.
[2] The Coal resources of the world, vol. 2, p. 500. Morang and Company Limited, Toronto, 1913.
Dowling, D. B., Geol. Surv., Can., Mem. 59, p. 121.

At present a good wagon road leads from Michel up Elk river to Weary Creek camp, a distance of approximately 45 miles, and the other parts of the district can be reached by pack trail.

RECONNAISSANCE ON GREAT SLAVE LAKE, NORTH WEST TERRITORIES.

(*A. E. Cameron.*)

The field season of 1916 was spent in making a general reconnaissance survey of the west arm of Great Slave lake. The party left Peace River crossing on June 3 in two canoes and travelling by Peace and Slave rivers reached Resolution on Great Slave lake on June 25. A month was spent, from June 25 to July 25, on a geological reconnaissance of the south shore as far west as Hay river. During this time two side trips were made, one to a lead-zinc deposit situated 10 miles inland south of Pine point, and the other a trip of 45 miles up Hay river to Alexandra falls. The remainder of July was spent in a traverse of the lower end of the lake from Hay river to the head of Mackenzie river and back along the north shore to Windy point. A micrometer survey of the north shore eastward from Windy point was commenced on August 1, and the traverse was closed at Hardisty island on August 25, approximately 100 miles of shore-line having been mapped. The north arm of the lake was crossed on August 26 and the journey back to Resolution continued under the shelter of the numerous islands of the northeast shore. Resolution was reached on September 6 and on the 10th the journey up river was commenced, Edmonton being reached just one month later.

As a basis for the work on the south shore W. Ogilvie's map of that shore was used. As stated above the party made its own survey of the north shore, and for the return journey to Resolution a copy of J. M. Bell's map of the north arm was obtained from Charles Camsell when he visited the party in August.

G. L. Kidd acted as assistant and rendered most efficient service.

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The writer wishes here to acknowledge his appreciation of the many kindnesses which he received at the hands of all with whom he came in contact during the work; to Mr. A. J. Vale and his assistants in the Anglican mission school at Hay river; to the Hudson's Bay Company's agents at the various posts visited; and particularly to the Forestry Branch of the Department of the Interior who allowed the party the use of their fire patrol steamers on the Slave and Athabaska rivers, thus eliminating the arduous trip of some 600 miles up those rivers to McMurray.

PREVIOUS WORK.

In 1886 R. G. McConnell made a traverse of the south shore of the lake from Resolution to Mackenzie river and the north shore as far east as the tar springs on Windy point. He also made a trip up Hay river to Alexandra falls. In 1899 J. M. Bell surveyed the northeastern shore of north arm and the islands lying between it and the south shore. Charles Camsell made a trip to the lead-zinc deposit situated south of Pine point in the course of his trip from lake Athabaska to Great Slave lake by Talston river in 1914.

With the exception of the reports of these men no extensive geological information on this district has been available, though practically all of the earlier

explorers of the north country, Hearne, MacKenzie, Franklin, Richardson, Back, and others traversed portions of the lake in their journeyings.

SUMMARY AND CONCLUSIONS.

The west arm of Great Slave lake is underlain by flat-lying Palæozoic sediments, probably largely middle Devonian in age, though possibly both lower and upper Devonian may be represented. Fossils are numerous and a considerable collection was obtained, but until these are determined no definite stratigraphic correlation can be made. Fossils collected in 1914 by Camsell at Resolution and Pine point were middle Devonian fauna equivalent to the Hamilton formation of Ontario and the Elk Point formation of Manitoba. The Pine Point collection represented a somewhat younger stratum than that at Resolution.

A collection of fossils made by R. G. McConnell from the shales on Hay river and determined by J. F. Whiteaves was said to be very suggestive of the Cuboides zone of European writers and the Tully limestones of New York. This would place the Hay River section as at the base of the upper Devonian.

West of Resolution no igneous intrusions were encountered nor was there observable, except in the vicinity of Pine point, any definite structure. The shore of the lake is quite low lying and rock outcrops, which are not numerous, are confined almost entirely to the more pronounced points which jut out into the lake, and to the larger islands. On the south shore rock outcrops usually occur as low shelves running up from the lake, showing few, if any, cut cliffs but frequently exhibiting a warping of the strata into small domes 100 to 200 feet in diameter and with dips seldom exceeding 5 degrees. Along the north shore bold, wave-cut cliffs 10 to 30 feet high are common. These occur at altitudes varying from 10 to 100 feet above the present lake-level and frequently at distances up to a mile and more inland. Numerous old lake beach ridges consisting of angular and subangular fragments of limestone also occur. At some points as many as forty of these old beaches were counted, the highest one being found at an elevation of 120 feet (aneroid) above the present lake-level. Remnants of similar lake terraces were found on the south shore at elevations of 250 feet (aneroid) and some 6 miles inland. These clearly indicate that in post-Glacial times the lake covered a much wider stretch of country than at present. On the north shore, where the limestones do outcrop at water-level, they form shelves similar to those found on the south shore and almost invariably show the small domes observed on the south shore.

In the vicinity of Pine point a low anticline with gently dipping limbs is clearly evident. It has a general strike of north 58 degrees west (astronomical) the apex being about one-quarter of a mile east of the point itself. On the western limb of the anticline are developed a number of the small domes already referred to as characteristic of rock outcrops on the lake shore.

Economic Geology.

A small deposit of lead and zinc occurs in a coarsely crystalline cavernous dolomite some 10 miles south of Pine point. A number of claims have been staked in the vicinity and a certain amount of prospecting work done, some of it in 1914. Since the galena is non-argentiferous the deposit does not seem to be of great value.

Copper staining is abundant in the Pre-Cambrian rocks on the northeast shore, but no workable deposits of this mineral were noted.

Practically all the rocks outcropping along the shore of the lake are more or less bituminous. On the islands east of Pine point coarse-textured, caver-

nous, and coraliferous limestones hold in the cavities appreciable quantities of pure bitumen. At Presqu'Ile point the limestones on fracture show a porous texture and the pores are frequently full of heavy petroleum. At Windy point on the north shore a massive-bedded dolomite carries considerable quantities of heavy petroleum. This seeps to the surface through fissures and along the bedding planes and losing its volatile matter forms tar pools. Numerous cold water sulphur springs accompany the oil seepage. There is no evidence of gas. The whole of Windy point has been staked in recent years for petroleum and natural gas.

To the north of Sulphur bay similar dolomites with petroleum seepages and sulphur springs occur.

The bluish green shales on Hay river weather readily to a very plastic bluish clay which is used by the natives at Hay River post as a wall wash for their houses. It appears to contain considerable quantities of lime but may be of value for the manufacture of common brick.

At Gypsum point at the entrance to the north arm the red arenaceous limestones carry beds of a flesh-coloured gypsum some 2 to 5 inches thick.

PHYSIOGRAPHY.

South Shore.

The south shore from Stony island as far west as Little Buffalo river is formed of delta deposits from Slave river. These deposits extend as far south as Fort Smith are typical cross-bedded sands and silts of fluvial origin. An abundant growth of excellent spruce covers portions of these deposits. At Resolution a low range of hills rises above the silts and is continued west into the lake as Mission and Moose islands, and still farther west as the Burnt islands. These were apparently islands in the older and much larger Great Slave lake, and have slowly been enclosed by the delta deposits of the river. They are typical roches moutonnées.

Little Buffalo river marks the western limit of the delta deposits and from there the shore-line is characterized by a series of wide shallow bays, the points between which are usually formed of thin-bedded bituminous limestones and calcareous shales. Inland the ground rises gently until at a distance of some 10 miles south it reaches an elevation of 300 feet above the present lake-level. This slope is well wooded with spruce, jack-pine, poplar, and willow and carries numerous, well developed, old lake beaches which, extending in long gentle curves, tend to follow the outline of the present lake shore. These beaches are formed of angular and sub-angular fragments of limestone indicating that the underlying sediments are not far from the surface, though no exposure was found.

A limestone shingle beach is developed in all cases where on the lake shore the rocks outcrop close to water-level. The shore at the heads of the bays is usually low and sandy and invariably carries numerous Pre-Cambrian erratics of various sizes.

West of a line drawn from Hay river on the south to Slave point on the north, the shores of the lake are formed presumably of soft shales, and the adjacent land is low lying and swampy. Long stretches of spruce and tamarac muskegs reach inland from the lake. These are bounded on the south by the Eagle mountains but the northern limit is not visible from the lake. Along the entire shore-line of this region Pre-Cambrian erratics are especially abundant and frequently are a source of danger to navigation as in places they occur some distance out from the shore.

The country lying to the south of the lake is well drained by a number of streams, the more important of which are Buffalo and Hay rivers. These streams together with Beaver river, which enters the Mackenzie a short distance below Great Slave lake, drain the country lying between Slave river on the east, Liard river on the west, and Peace river on the south. Where they cut across the limestones the rivers are broken by falls or series of rapids. Alexandra falls on Hay river are of particular beauty. The only geological section of importance observed during the season's work was measured at the falls and in the gorge below.

North Shore.

From Slave point the shore of the lake extends north for a distance of about 40 miles, thence east for 25 miles, and thence swings in a wide circle to the north arm.

The entire shore-line shows clearly the effects of excessive glacial action. Many deep narrow bays stretch inland approximately parallel to one another in a direction about south 60 degrees west (magnetic) or north 80 degrees west (astronomical). That this direction is parallel to the glacial movement is shown by well marked striæ on Windy point.

The heads of the bays are usually low and swampy, as they are on the south shore and hold many Pre-Cambrian erratics. Wide marshy regions, in many cases containing large open sloughs, stretch inland from the bays. On the broader points, rock outcrops occur as bold wave-cut cliffs 25 feet high, having a general direction north-south (astronomical) or approximately at right angles to the direction of glacial movement. On the narrow points few rock outcrops occur but the abundance of limestone shingle shows that bedrock is not far from the surface. Large Pre-Cambrian erratics occur on all the points. Some of the erratics are undoubtedly of glacial origin, but many are probably ice rafted.

Distinct barrier beaches of limestone shingle are developed wherever the bedrock outcrops at water-level. Many of these, extending in long gentle curves, enclose shallow, partially filled lagoons.

The inland country is of low relief but is characterized by numerous long narrow hills rising some 100 to 150 feet above the lake level. These are typical roches moutonnées and show steep, wave-cut cliffs on the eastern ends. The low ground among the hills is a spruce and tamarack muskeg with an elevation only slightly above that of the lake. One of the pronounced features of this region is the absence of drainage towards the lake. Throughout the entire 100 miles of shore-line examined no stream of any importance was found entering the lake.

Northeastern Shore.

The north arm marks the contact of the Pre-Cambrian rocks on the east and the Palæozoic sediments on the west. Consequently, the northeast shore, which is formed of the Pre-Cambrian rocks, has a character entirely different from the others. There the shore is rocky throughout and for a great part barren of vegetation except in the hollows. Boldly carved and rounded hills of igneous and metamorphic rocks break off abruptly at the lake, and off shore are numerous irregularly shaped rocky islands. The shore is deeply indented with many narrow bays and inlets which are usually deep and afford excellent harbourage for small crafts.

The eastern arm of the lake, stretching some 200 miles from the mouth of Slave river, is surrounded by Pre-Cambrian rocks of the Laurentian shield. It is reported to be full of islands and to show no large expanse of water comparable

to the west arm. The water is said to be very deep and clear and abounds in fish. Lake trout (*Salvelinus namaycush*), many of them attaining weights of over fifty pounds, are especially abundant.

The western arm is slowly being filled up by the material brought down by Slave river. Though this arm is a very large expanse of open water and free from islands beyond 10 miles from shore, it is everywhere shallow and sand or gravel bars are reported to occur many miles out. The water is never entirely clear of suspended matter and sand and gravel bars covered with water barely 5 feet deep occur at distances of 2 miles or more from shore. The prevailing winds being from the north, immense quantities of driftwood have collected all along the south shore. Piles of this material 50 and more feet wide and several feet high extend for many miles along the beaches.

This arm of the lake also is well supplied with fish, the most abundant of which is white fish (*Coregonus clupeiformis*). There are also lake trout (*Salvelinus namaycush*), inconnu (*Stenodus mackenzii*), pike (*Esox lucius*), sucker (*Catostomus longirostris*), and others of less importance.

GENERAL GEOLOGY.

No definite correlation can be made between the rocks of the south and north shores until the fossils collected have been determined, but from lithological evidence it would seem as though the limestones and dolomites occurring at Windy point lie intermediate between the soft shales of the Hay River section and the limestones found at Sulphur point. At the lead-zinc deposit situated south of Pine point the country rock is a fissured, porous, and cavernous dolomite which conforms lithologically with the tar-bearing dolomites of Windy point. This is the only case where even a tentative correlation can be suggested. For the most part the sediments found on the south shore, the Hay River section, and on the north shore all have points of marked similarity and of marked difference. They are all thin-bedded shaly limestones of similar texture and lithological character, and are usually more or less bituminous. The more bituminous beds are invariably those which contain more abundant fossils. This fact holds particularly in those cases where the typical fossils are corals or bryozoa.

Throughout the entire field area, except in the vicinity of Pine point, no definite structure section was obtainable. A general dip to the west at an angle of about 3 degrees appears to hold over all the area. Wherever outcrops occur at water-level or near it a warping of the strata into small local domes is evident. These have diameters of from 100 to 200 feet and have dips seldom exceeding 5 degrees. In a few cases where these shelving outcrops occur soundings were taken at some distance from the shore, and it was found that the shelves break off into deeper water forming submerged cliffs similar to those found above water-level on the north shore. Moreover, it was found that in all cases where the thin-bedded limestones outcrop at water-level the dip of the strata is apparently towards the lake.

The domes may have been formed by the transformation of anhydrite beds at depth into gypsum with the consequent increase in volume. This theory is supported in several cases, particularly those at Sulphur point on the south shore and on Windy point on the north shore, by the presence of large sulphur springs in the vicinity, though in no case was a spring actually found on one of the domes.

Description of Outcrops.

Resolution. On Mission and Moose islands and in the vicinity of Resolution the shore is characterized by much limestone shingle and in numerous places the

limestone itself is uncovered. Where exposed it consists of white to grey weathering, fine-grained, dark grey, thin-bedded limestones. Fossils are not numerous but the rocks weather with a very irregularly pitted surface as though fossils had weathered out. Some of the beds, which are from 2 to 3 inches thick, are even-textured but usually they are mottled in appearance and made up of light grey, fine-grained portions and dark grey coarser-grained portions. Very little bitumen appears to be present. The beds lie practically horizontal and the thickness of strata exposed is not great. In nearly all cases the outcrops show decided evidence of local doming. The crests of the domes are badly fractured and fissured and the fissures are filled with a clear white calcite.

Vicinity of Little Buffalo River. A continuous sand beach without outcrops of the solid rocks extends from Resolution to the mouth of Little Buffalo river and the inland country is undoubtedly formed of the delta deposits of Slave river.

The shore west from Little Buffalo river is a continuous limestone shingle beach for a distance of 4 to 6 miles. In a number of places the lake ice has shoved back the overlying shingle and exposed the bedrock beneath. The limestones here are white weathering, fine textured, and thin-bedded; the beds are from 4 to 5 inches thick and are usually reddish brown in colour. They contain more fossils and appear to be more bituminous than those about Resolution. The surface beds are much fractured by frost and wave action and in some cases are fissured with veinlets of calcite. Local doming is frequent but a general dip of 1 or 2 degrees to the west is noticeable. Numerous alkaline and iron bearing springs, which stain the shingle a dark red colour along this section, appear to have their origin from the same stratum. The water of the springs tastes strongly of iron and alkali salts but contains no appreciable amount of sulphur.

A flat-topped hill about 200 feet high, situated inland $1\frac{1}{2}$ miles, and about 7 miles southeast of Pine point, is capped by a heavy-bedded, soft, yellow, calcareous sandstone. The weathered surface has a white to grey colour and is greatly pitted. No determinable fossils were collected, though in one or two cases the outline of a tightly coiled gasteropod was noted. A maximum dip of 3 degrees to the west was measured. At no other point in the district examined during the summer was there noted a rock similar to this.

Pine Point. In the vicinity of Pine point there is definite anticlinal structure and it was found possible to compile a geological section of the rocks exposed. Blue-grey weathering, hard, calcareous shales and thin-bedded limestones predominate. All are highly bituminous and fossiliferous.

On the islands to the east of the point similar sediments outcrop at various places. These islands seem to have been formed by the doming up of the underlying rocks and the beds exposed are apparently lower than those found on Pine point, though probably of the same series. A tentative correlation was made between the lowest beds exposed in the anticline and the uppermost beds exposed on the islands. The rocks are thin-bedded bituminous limestones, highly fossiliferous, and in some cases in the more massive beds a porous cavernous structure was found, the cavities being filled with bitumen. The following sections exposed on Pine point and the islands to the east were measured:

Section at Pine Point.

	Thickness Feet	Thickness Inches
Thin-bedded limestone	..	8
Fossiliferous and bituminous shale	..	8
Dark brown, oily shale	1	..
Thin-bedded limestone	..	4
Concretionary bituminous, calcareous shale	6	..
White weathering limestone, nodules in dark shales, all bituminous	2	..

Section on the Islands East of Pine Point.

	Thickness Feet	Inches
White weathering limestone, nodules in dark shale, all bituminous	4	..
Dark hard shales, limestone bands	1	2
Limestone breccia in shale	..	4
Thin-bedded bituminous limestone	1	6
Dark bituminous shale	..	10
Argillaceous limestone, bituminous	1	2
Interbedded bituminous shales and limestones	1	6
Massive limestone, hard, bituminous	1	8
Dark bituminous shale	..	4
Massive limestone, fine textured, hard, cavities with bitumen	6	6
Dark bituminous hard shales	1	..

Presqu'lle Point. On Presqu'lle point limestones that are in a general way similar to those found about Pine point are exposed wherever the action of lake ice and waves has removed the overlying shingle. The limestones are in heavier beds than those of Pine point and are all highly fossiliferous, the fossils weathering out readily and being in a good state of preservation. Some of the beds on fracture show a porous structure and give a seepage of heavy petroleum.

Sulphur Point. At Sulphur point a wave-cut cliff about 10 feet high is made up of thin-bedded limestones and calcareous shales generally similar to those found in the vicinity of Resolution and Little Buffalo river and like them, carrying few fossils and only slightly bituminous. No definite dip to the strata was obtained but many local domes are present. On the west side of the point there is a very large sulphur spring.

From Sulphur point west no outcrops were noted on the south shore, though most of the points show limestone shingle beaches.

Hay River Section. The deep valley of Hay river between Alexandra falls and the lake, gave the only geological section of any great thickness encountered during the work. This section was studied in some detail. The geological section which follows has been compiled from sections taken at various places on the river.

Hay River Section.

	Thickness Feet	
Massive arenaceous limestone	30	
Thick and thin-bedded limestones, shaly bands with fossils, very fine-grained, grey	62	
Coraliferous limestone, bituminous	16	
Red-brown, medium-grained limestone	12	
Blue-grey shale	5	
Reddish sandstone, ripple marked	7	
Blue-grey, soft shales	47	
Massive, red-brown limestone	8	
Shaly limestone, many fossils	12	
Thin-bedded brown limestone	21	
Blue-green, clay shales, limestone layers with many fossils	42	
Highly fossiliferous limestone	20	
Blue-green, clay shale	15	
Flaggy sandstone, shaly layers with ripple-marks and worms	14	
Fossiliferous limestone	8	
Blue grey clay shale	28	
Thin-bedded, fossiliferous limestone	8	
Blue-green clay shales, limestone bands with fossils	105	
Thin-bedded limestone, fossils	8	
Blue-green clay shales	10	
Sandstone, ripple-marks and worms	12	
Blue-green, clay shales, limestone bands with fossils	90	(aneroid)
Thin-bedded limestone, shaly, argillaceous	25	
Blue-green clay shales, bottom not exposed	..	
	605	

The top of the section as exposed at the Alexandra falls shows 120 feet of thick and thin-bedded cream weathering limestones. Fresh fracture shows a light brown to grey colour and a fine texture. Between the more massive beds occur thin calcareous shale bands usually more fossiliferous than the limestone. Twelve feet from the bottom of these limestones occurs a series of massive bedded highly coraliferous and bituminous white weathering limestone 16 feet thick. This is the only series of beds which shows any bitumen in the Hay River section.

Below the limestones are 5 feet of a blue grey shale, then 7 feet of a reddish, ripple-marked and wormy sandstone, and then 47 feet of a blue grey shale as above. This superposition of hard limestone on soft shale has produced Alexandra falls and a similar succession of sediments is the cause of the lower falls.

A limestone series 41 feet thick occurs below the blue-grey shales and this is underlain by about 400 feet of a very soft bluish-green coloured shale containing thin layers of highly fossiliferous limestones and cross-bedded and ripple-marked sandstones. The layers vary in thickness from a few inches to 20 or more feet and are more numerous towards the top of the shales. No fossils were found in the shales themselves but those in the limestone bands weather out readily and become intimately mixed with the shales in the talus slopes.

The bottom of the section is not exposed and it would appear as though that portion of the lake basin lying to the west of Hay river has been carved out of these soft shales.

Slave Point. On the east shore of Slave point flat-lying, thin-bedded limestones outcrop, apparently dipping slightly toward the lake. The beds are from 2 to 5 inches thick and a maximum section of less than 2 feet is exposed. They consist of a white weathering, fine textured, grey, shaly limestone. Fossils are fairly abundant and the limestome is quite bituminous. At one place a small sulphur spring was noted and the interior of the point contains a large, open, gravel and clay area, apparently the basin of a large alkaline sulphur spring now dried up. Large quantities of decayed and salt encrusted timber are scattered about this area, many pieces having the yellowish tinge of sulphur. A peculiar feature of this region is the apparently rapid disintegration of the Pre-Cambrian erratics which are abundant in the old spring bed. Decayed and rotten granite boulders are very numerous.

Windy Point. The southeastern shore of Windy point is characterized by wide limestone shingle barrier beaches. At the southeastern extremity of the point a wave-cut cliff 15 feet high begins and extends north in a straight line for some 3 miles. Just opposite the easternmost portion of the point the cliff is about one-half a mile inland and between it and the lake shore are the remnants of numerous old lake beaches of limestone shingle. Above the cliff the ground rises in a uniform slope to a height of about 100 feet and extends as a flat tableland into the interior. This slope also shows many old lake beaches; from the top of the hill to the shore forty-one were counted.

The sediments exposed in the cliff are medium to thin-bedded, cream weathering limestones and calcareous shales. Fresh fracture shows red to brown colours and a medium grain. Practically all the beds are highly fossiliferous and bituminous. A vein of calcite averaging 2 inches in width contained appreciable quantities of coarsely crystallized galena.

The northeast portion of the point is composed of a porous and cavernous dolomite or magnesian limestone. The dolomites are badly fractured and fissured and along the fissures and between the bedding planes numerous seepages of petroleum occur, accompanied by large sulphur springs. Fresh fracture shows a dark brown, crystalline, bituminous, magnesian limestone changing to a white coarsely crystallized dolomite. Cavities are common and are invariably lined with curved rhombohedral crystals of dolomite. The cavities are usually

filled with heavy petroleum. Fossils are rare but the lower beds contain a few tightly coiled gastropods. The petroleum seepages occur most abundantly in the vicinity of this fossil horizon.

Sulphur Bay. Sulphur bay, a deep, narrow mouthed bay lying to the north of Windy point, has at various places on its shore outcrops of petroleum-bearing dolomites identical with those of Windy point. Strong flowing sulphur springs are quite abundant. A range of hills some 250 feet high, rising from the shore at the north side of the bay, is formed of the dolomites. Some of the beds contain bryozoa and brachiopods similar to those found in the thin-bedded limestone on the south end of Windy point. Tar springs comparable in size to those of Windy point were found at an elevation of 200 feet above the lake and inland about a mile. A well-cut sleigh trail runs over this range of hills to a small lake about 5 or 6 miles inland.

Sulphur Bay to Gypsum Point. East from Sulphur bay thin-bedded limestones outcrop practically wherever a point extends eastward into the lake. The beds which are covered with limestone shingle, are flat-lying and usually characterized by small local domes similar to those found on the south shore. Wave-cut cliffs are frequent though usually at varying elevations above the present lake-level. Where exposed the sediments are thin-bedded, shaly limestones, highly fossiliferous and generally more or less bituminous. Corals, bryozoa, and brachiopods are the principal fossils and the limestones are usually more bituminous where corals predominate.

Gypsum Point. At Gypsum point and along the southwest shore of the north arm, red coloured thin-bedded calcareous sandstones and arenaceous limestones, ripple-marked and cross bedded, outcrop in various places and hold, between the bedding planes, thin seams of flesh-coloured gypsum. Some of the gypsum is well crystallized into long satinspar crystals and shows distinct evidence of deposition from solution. No fossils were obtained from these beds.

ECONOMIC GEOLOGY.

Petroleum.

Almost all the limestones outcropping on the lake shore are more or less bituminous and some on fracture give a distinct seepage of heavy petroleum.

At Windy point a massive-bedded dolomite is exposed which is highly impregnated with oil. Several tar pools are formed where this oil, on reaching the surface, has lost its more volatile constituents, partly by evaporation and partly by absorption by the mosses and soil. Wherever seepages occur on bare rock, oil pools collect in the hollows and crevices.

The dolomite is white or grey weathering and coarsely crystalline. Fresh fracture shows a cavernous and porous structure, the cavities usually holding considerable quantities of oil. In places it has the appearance of a mixture of a dark brown, bituminous crystalline, magnesian limestone, and a more coarsely crystallized white dolomite. The rocks are badly fractured and fissured and show distinct evidence of local doming, similar to that so frequently found on the south shore. The tar and oil pools occur along these fissures and along the bedding planes. Cold water sulphur springs are numerous, being especially abundant just at water-level.

With regard to rock structure little can be said. As already noted there is evidence of a considerable number of small domes but, other than these, no definite structure was noted. The sediments outcropping in the cliff at the southern extremity of the point, show, at the base, a flat-lying, thin-bedded, fine-textured grey limestone and similar beds appear to be directly below the dolomites.

There is nothing to show that a decided break occurs in the strata between the limestones in the cliff and the dolomites.

With regard to the possibilities of the existence of an oil field of considerable extent here the following notes are of interest.

"There are four necessary geological features that an oil field must have before it can become productive:

(1). A supply of liquid oil of sufficiently low viscosity to flow through the pores and cracks of the oil sand at the temperatures obtaining where the oil is found.

(2). A container, porous in itself, as in the case of a sandstone, or made so by fracturing or other changes as in a shale, limestone, chert, or dolomite.

(3). An impervious capping over the container, imprisoning the oil until it is released by the drill. The capping is usually a shale.

(4). A rock structure favourable for the accumulation of the oil in reservoirs from which it may be obtained when tapped by a drill."

So far as could be found, at no place on the lake, with the possible exception of Pine point, were all these conditions fulfilled. At Windy point there is apparently oil and the dolomites would act as a container. On the other hand no impervious capping overlies the dolomites, and the structure as exposed on the surface does not seem favourable. It is, however, possible that a suitable capping may occur at depth and the small domes noted may be only the very tops of more pronounced domes lower down.

A possible explanation of the oil seepages on Windy point is as follows:

The sulphur-bearing waters rising from below carry considerable quantities of calcium and magnesium salts and percolating through the overlying thin-bedded limestones change them to crystalline magnesian limestones and dolomites. In the process the bitumen is set free and forced either into the cavities formed in the dolomites or through the fissures, developed during dolomitization, to the surface to form the tar and oil pools.

The field facts upholding this explanation are:

Certain portions of the beds are not yet completely changed to dolomite but are made up of a coarsely crystalline, white dolomite mixed with a more finely crystallized, dark brown bituminous, magnesian limestone. No distinct line of separation exists between the two phases but there is a gradation of one into the other.

In places the outlines of fossil remnants are distinctly visible. In the neighbourhood of Sulphur bay to the north of Windy point similar dolomites occur and there distinct fossils are numerous, though they show a partial recrystallization into curved rhombohedral crystals of dolomite.

A partial qualitative analysis of salt encrustations from the vicinity of one of the large sulphur springs in Sulphur bay gave abundant sulphate and carbonate salts, principally of calcium but with an appreciable amount of magnesium.

No natural gas accompanies the oil.

A sample of the oil from Windy point, collected by Mr. Camsell, on analysis by E. Stansfield of the Mines Branch, gave the following results:

Specific gravity crude oil at 15·5°C. 0·957.

Preliminary distillation of 203·7 grams crude gave 122·2 grams oil distillate of 0·888 sp. gravity. This is 60 per cent by weight or 64·5 per cent by volume of the crude oil.

Fractional distillation, Engler apparatus of 100 c.c. oil distillate taken gave 1st drop at 178° C., at 178° to 300°C. gave illuminating oil, etc. 23 per cent by vol., 0·855 sp. gr., equivalent to 14·9 per cent by vol. crude oil.

Residue, lubricating oils, etc., 77·0 per cent by vol., equivalent to 49·6 per cent by vol. of crude oil.

Calorific value of crude oil, 10,040 gram calories. 18,070 B. T. U. per pound.

Sulphur in crude oil, 1·0 per cent.

Lead-Zinc Deposits.

About 10 miles south of Pine point and at an elevation of about 250 feet above the lake, a flat-lying crystalline dolomite outcrops in places over an area of several square miles. The dolomite is grey weathering, white, and quite coarsely crystalline. Fresh fracture shows a porous structure and many cavities in which typical curved rhombohedral crystals of dolomite occur. Large sink holes 10 to 20 feet deep and as much as 200 feet in length are numerous.

At one place a slight folding of the strata into a broad anticline is developed. The western limb only is exposed and has a dip of 5 degrees to the west and a strike of north 20 degrees east (magnetic). The crest of the fold is badly fractured and fissured and there the dolomites are impregnated with considerable quantities of galena and some sphalerite. Exceptionally large sink holes occur just to the east of the crest and expose shallow sections of the dolomites.

The general structure shows a massive bedded dolomite. Along the bedding planes of this dolomite the mineralizing solutions have percolated and impregnated the overlying beds. In some cases the galena is evenly dissiminated throughout the bed but usually is most abundant in the lower 18 or 20 inches. Some of the beds are more highly impregnated than others. Associated minerals are a very light coloured sphalerite and some small amounts of pyrite. Sphalerite seems to increase at depth.

A considerable number of claims have been staked in the vicinity and some prospecting work done, though very little in recent years. The prospect pits are all now badly caved so that no data were obtainable from them.

The mineralized area appears to be small and confined to the anticline where fissuring has allowed the mineralizing solutions access to the dolomites. Since the galena is non-argentiferous the value of the deposit does not seem very great.

INVESTIGATIONS FOR COAL, OIL, GAS, AND ARTESIAN WATER IN WESTERN CANADA.

(*D. B. Dowling.*)

COAL.

Alberta. The locations of new areas in which coal mines have been opened in Alberta during the past year seem to have been determined by the advance of railway construction. The settlement of the Grande-Prairie district has been followed by the opening of seven small mines, evidently to supply coal for local consumption. The total output of the mines in the province has been greatly increased and the larger mines in the mountain and foothill areas have resumed work on as large a scale as labour conditions permit. In the general work of exploration or tracing out new areas, our efforts have been resumed in the foothills north of the Grand Trunk Pacific railway. It may be said that more or less definite information is already at hand or published concerning the location of the principal coal fields from the International Boundary to Athabaska river. From there north to Sheep creek, a branch of Smoky river, John MacVicar has traced portions of three folds or basins of the coal-bearing series and has determined the thickness and character of many of the coal seams found. His report on page 85, shows the great value of this new area, not only in the possible amount of coal available, but also in the high character of the coal sampled.

Several mines recently established in the edge of the mountains and connected to the markets by railways, were visited by J. S. Stewart who contributes des-

criptions of the measures at Nordegg, Lovett, Coalspur, and Entwistle. The last mentioned is on the main line of the Grand Trunk Pacific railway, Lovett and Coalspur are on branch lines, and Nordegg is the terminus of a branch of the Canadian Northern railway in the valley of the North Saskatchewan river.

A general study of all the coal areas between Pincher Creek and Fernie is being made by Bruce Rose. This investigation is dependent on the progress made in mapping the area and will extend northward to latitude 50 degrees.

A report embracing the results of a previous season's study of the geological formations of the plains of southern Alberta has been written and includes notes on the distribution of the coal areas. This report, with map illustrations, is in press and will shortly appear as Memoir No. 93.

A personal visit was made to the mines opened in the valley of Red Deer river at Drumheller. Two seams of coal are being mined and, as this locality is becoming of importance, a short description of the measures is appended.

The production of small coal at all the mines is probably greater than that of the mines of the coast areas. Where the coal is of a coking quality this is easily disposed of in making coke or used in run of mine coal. Where the coal is non-coking, the problem has been difficult. The anthracitic small coal at Bankhead has been successfully briquetted; but the small coal from the sub-bituminous mines of the prairie has been generally wasted. Experiments at the power stations of Edmonton, Prince Albert, and Saskatoon have demonstrated the feasibility of burning this fine coal and thereby cheapening the cost of power. It is hoped that by this means the waste will be greatly lessened.

Saskatchewan. The main productive coal areas of Saskatchewan seem to be those in the southern portion of the province, although isolated seams have been found in the western part. An examination of the Wood Mountain-Willowbunch area was conducted by Bruce Rose during the seasons of 1913-1914, and a summary report was published. His final report and map, giving greater detail, is now available as Memoir No. 89. The large area lying east of this, on which the only available information is contained in "Report on the Souris coal field,"[1] is being investigated by A. MacLean, who spent the past season in this field and contributes a short summary report.

The coal of Saskatchewan is of lower quality than that of Alberta and may be called a black lignite. It is available for immediate use in ordinary stoves but disintegrates rapidly on exposure owing to its high moisture content. To provide a stable fuel of greater value, the provincial government has carried out a series of experiments on the possibilities of drying and briquetting and of charring and briquetting. The latter process seems to be commercially successful, the resulting fuel being of about the grade of the coal mined at Lethbridge, Alberta. The problems to be solved are the finding of a suitable binder for the briquettes and the utilization of the surplus gases given off in the charring of the lignite. This process allows of the collection of many of the by-products of distillation and seems to open up a fruitful field of study in the way of developing industries for treating these by-products.

OIL.

Alberta. Boring during the past season has been confined to three widely separated areas: Sheep River area southwest of Calgary; Viking area east of Edmonton; and the area at Peace River Landing. In the Sheep River area the boring has been for the purpose of extending the area known to produce oil; thus, in the vicinity of the Dingman well from which a small amount of oil has been obtained, it is proposed to drill another well near the northern edge of the property and near the producing well of the Southern Alberta Company. The

[1] Publication No. 786.

latter company have also drilled a second well. Small flows of oil have been found in the wells to the south and west of the Dingman. A more definite statement is contributed by S. E. Slipper on pages 114-117.

In the Viking area, a small showing of a dark, thick, asphaltic oil was obtained in the second well put down in that district. These wells were bored primarily for natural gas; and the oil indications though small, are interesting, but do not affect the general policy of boring.

In the Peace River area, a well has been drilled near the banks of the river below Peace River Landing. According to newspaper report, some oil was obtained at comparatively shallow depths in the Peace River sandstones. Apparently the tar sands exposed on Athabaska river were not reached.

NATURAL GAS.

Alberta. The gas fields of the southern portion of the province form the subject of a very interesting compilation by Mr. Slipper (see pages 124-134). From a study of the general structure of the area and of the borings south of Foremost he finds that the area has much greater possibilities than formerly supposed; it may even be surmised that in the anticline which extends to the International Boundary, gas fields, possibly of greater producing value than those now proved, will be found. Of the two sandstone formations underlying the anticline the upper is exposed in Milk River valley and has become saturated for a long distance with fresh water from the river, thereby retaining the gas. The Medicine Hat natural gas is derived from this sandstone. The lower sandstone outcrops on the sides of the Sweet Grass hills; but by intersecting dykes of igneous material the outlet which would have been formed at the outcrop has been practically closed. The gas has accumulated in the part of the section which is about 300 feet above sea-level. Below that level, salt water is present. Several tests of the gas have been made for the presence of gasoline and small amounts are reported to have been obtained by absorption in heavier oils.

The value of the gas as fuel is satisfactory. Tests for the production of carbon black were made at the request of Arthur D. Little, Limited, Montreal, and the results will probably be published by them.

The presence of gas at Foremost should stimulate the manufacture there of clay products, especially as the completion of the Weyburn branch of the Canadian Pacific railway will give access to the fireclay deposits of the Cypress hills, which are probably capable of furnishing material for many grades of earthenware. Gas is still being obtained from the Dingman well on Sheep river and is used for power purposes at the wells being drilled in the vicinity.

A small flow of gas has been obtained in various wells east of the Calgary-Edmonton railway. The latest reported find is at Ponoka, in a well drilled by the local government for the provincial asylum. Extensive preparations are being made to bore for gas on the anticline east of Edmonton. Five wells have been bored at Viking on the line of the Grand Trunk Pacific railway and fairly satisfactory results obtained, but the flow of gas is not sufficient for a large city. The results at Viking have stimulated exploration in other parts of the district and several borings are to be started in the area to the southeast with a view to securing a supply of natural gas for the cities in Saskatchewan. A personal visit was paid to the area south of Sounding lake, where, it was reported, the underlying rocks lay in inclined positions indicating possible lines of fracture. Several of the exposures seen show that the area will require very close study to determine the structure and its possible bearing on oil and gas possibilities. The northern edge of the anticline was visited by J. S. Stewart toward the close of the field season; but as the visit was intended to be preliminary to a general survey of the field later, no detailed report has been prepared.

Saskatchewan. It is reported that a syndicate is now boring for gas on sec. 22, tp. 34, range 28, W. 3rd mer., and in other localities for the supplying of gas to the city of Saskatoon. Small flows of gas have been obtained in shallow wells in the Estevan district in measures known to contain coal. Owing to the somewhat porous nature of the covering beds it is not expected that very large volumes of natural gas will be obtained there. A trial well has been under way at Hanley south of Saskatoon, but the results have not been reported.

ARTESIAN WATER.

In southern Alberta an area, in which artesian water could be obtained at reasonable depths, was outlined on a small map published in the Summary Report for 1915.[1] This supply was to be found in sandstones at depths of between 700 and 800 feet and should flow at the surface. It was urged upon the department that this theoretical statement should be proved by boring in the areas within the extreme limits given. As there were in the eastern and western parts wells to sustain the theory, two wells in the central part were determined upon and contracts were given for the drilling.

The locations of the wells under contract are:

On road allowance between secs. 11 and 12, tp. 8, range 13, W. 4th mer.
On road allowance north of sec. 19, tp. 9, range 10, W. 4th mer.

As it was late in the season when drilling started and as labour was scarce the progress of this work has been slow and the wells are not yet completed. Should they reach the artesian water-bearing sands the whole area will have been fairly satisfactorily proved.

Other wells reaching the water-bearing sands of the area are the following:

(1) Well drilled for the town of Taber, Alberta.
Depth to water bearing strata 670 feet.
Flow of water several thousand gallons per day.
Slight trace of soda-bicarbonate.

(2) Well on sec. 8, tp. 10, range 15, W. 4th mer.
Flowing well, no record.

(3) Well east of Purple Springs, sec. 16, tp. 10, range 14, W. 4th mer.
Depth to water-bearing strata 655 feet.
Water and gas flowing at surface in 1915.
Partly clogged up in 1916, no casing at bottom.

(4) Well on farm of Dase Brothers, on sec. 36, tp. 8, range 15, W. 4th mer.
Reported 895 feet deep. Intermittent flow gas and water.

(5) Well No. 18, Canadian Western Natural Gas, Light, Heat, and Power Company.
Sec. 2, tp. 11, range 12, W. 4th mer.
Water-bearing sand 730–739 feet below surface.

(6) Well No. 19, Canadian Western Natural Gas, Light, Heat, and Power Company.
Sec. 25, tp. 10, range 12, W. 4th mer.
Water-bearing strata 680–715 feet below surface.
Flow of water strong, filled cellar of derrick twice daily and overflowed pipe when pulled up in derrick 30 feet. The casing was then driven down to shut off this water.
Practically the same conditions prevailed in all the other group of gas wells of this area (Bow Island gas field).

(7) Well at Foremost, sec. 20, tp. 6, range 11, W. 4th mer.
Depth 725 feet. Head of flow above surface 30 feet.
Measured flow 7,000 gallons per day.

(8) Well No. 3, United Oils Company, Etzikom coulée.
Sec. 31, tp. 5, range 10, W. 4th mer.
Water-bearing sands at 500–600 feet. Flow of water 16,000 gallons per day. This was cased off and the well deepened.

(9) Wells of Beaver Oils Company, Milk river.
Sec. 24, tp. 2, range 11, W. 4th mer.
Flow of water from sands at 165 feet very large, from two wells about 200,000 gallons per day.

[1] Geol. Surv., Can., Sum. Rept., 1915, pp. 102–110.

Many shallower wells have been bored in this district and a supply of water has been obtained from the strata containing coal seams at depths of 300 to 400 feet. This water does not rise in the wells and is pumped.

Drumheller Coal Area.

The deeply eroded valley of Red Deer river exposes, east of the foothill area, the slightly uptilted rocks of several formations; in section these strata pass successively from the sandstones of the Paskapoo formation, through the thinner bedded and generally softer deposits of the Edmonton, the shales of the upper marine portion of the Pierre, and the brackish water beds of the Belly River series. The coal horizon belonging to the top of the Edmonton formation is exposed near the Grand Trunk Pacific railway at Bullockville.

Near the mouth of Threehill creek, the banded shales and-sands of the lower part of the Edmonton formation are exposed in the valley and several coal seams have been found in them. This series, owing to a low northwesterly dip forms the banks of the valley for some miles below the mouth of Rosebud river. Beneath this series there is a series of dark marine shales which gradually rise in the banks and reach prairie level above the mouth of Bullpound creek.

The cutting of Red Deer valley across the coal zone in the lower Edmonton rocks affords many points from which the several coal seams may be attacked. The thickest and probably the most continuous seam is the one found at water level in Red Deer river near the mouth of Rosebud river. Upstream in each of these valleys the seam descends beneath the river grade owing to a low dip in the seam and to the grade of the streams. The seam is being mined in many places along the Red Deer and Rosebud valleys and is commonly referred to as the Drumheller seam. Above and separated from it by about 70 feet of beds, lies the Newcastle seam which is mined just west of the town of Drumheller. The seam is exposed or comes to the surface at the level of the railway at the station and is seen in the cut banks opposite the town. Eighty-two feet above this seam, there are traces in the cut banks of a third seam, called here the Vulcan seam, which is mined on Michichi creek. In places all these seams are mineable and the building of the Calgary-Saskatoon branch of the Canadian Northern railway made the markets available so that closely following the completion of the railway several mines were opened.

Geological Section.

The rocks exposed in the vicinity of Drumheller comprise the lower part only of the total section in this vicinity. The incision of the valley must represent a trenching of at least 400 feet. The elevations given by the railway surveys, show a rise of 400 feet in the grade between Drumheller and Munson, about 6 miles north. In the upper part of the banks of the stream the slopes are generally grass-covered, but there are traces of river deposits, consisting of washed sands, on some of the shoulders, and yellow clays in the higher levels. In the immediate vicinity of the river the strata containing the coal seams are well exposed and although they do not resemble the measures at Edmonton they seem to occupy a similar position in the Edmonton series. The main difference is mostly in the banded appearance of the exposures and their generally pale colour. The coal seams, although possibly not continuations of those at Edmonton, may be correlated with them as occupying somewhat similar positions in the geological section. The heaviest seam and the one most generally worked is the lowest of a series of three or four.

The Drumheller section as exposed near the town, is contributed by Mr. Jas. Hargraves:

Section at Drumheller below Vulcan Seam, North Bank of Red Deer River.

	Feet	Inches
Vulcan seam (Maple Leaf mine) (coal....1 ft. 6 in.) (bone... 0 ft. 8 in.) (coal....2 ft. 0 in.)	4	2
Light coloured, banded clays with streaks of lignite. Thin beds of sandstones lightly and irregularly cemented occur in the central and lower parts........	82	4
Newcastle seam. Irregular in thickness, generally thins to east..................	4	0
Measures in bore-hole......Shale..........26 ft. 0 in.; *Coal*.......... 2 ft. 0 in.; Shale..........16 ft. 0 in.; Sandstone..... 11 ft. 6 in.; Shale.......... 5 ft. 0 in.; Sandstone ..... 7 ft. 0 in.; Shale.......... 5 ft. 0 in............	72	6
Drumheller seam..	8	0
Shale floor.		

The section near the mouth of Rosebud river was not measured by the writer, but a section, measured by Mr. B. W. Dunn and published in the prospectus of the Rosedale Coal and Clay Products Company, Limited, seems to be quite representative of this district and is here repeated for comparison with that at Drumheller. The lower seam mined here is thought by many to be the same as the Drumheller seam and is at the base of the section herewith given.

Section at Rosedale.

	Feet	Inches	
Stratified clay at top of bank, thickness up to..............................	150	0	
Earhty clay (gypsum crystals)..	8	0	
Sandstone, unconsolidated..	3	0	
Ironstone..	0	2	
Sandy clay shale...	10	0	
Soft sandstone, with streaks of clay.....................................	3	10	
Soft sandstone irregularly hardened......................................	2	0	
Band of "tie stone" (probably harder sandstone)..........................	0	4	
Clay shale...	11	0	
Ironstone..	1	0	
Clay shale...	5	5	
Lignite..	0	9	
Loose clay shale...	3	8	
Lignite..	0	6	
Shaly sandstone..	5	3	
Ironstone..		1" to 6"	
Coal...	7	3	
Clay shale...	10	9	85 ft. 3 in.
Ironstone..	1	0	
Lignite..	2	0	
Clay shale...	2	4	
Sandstone with clay streaks..	5	7	
Ironstone..	0	2	
Sandstone, iron stained..	3	5	
Lignite..	1	2	
Sandstone, clay streaks..	4	0	
Ironstone..	0	3	
Sandstone, clay streaks..	2	10	
Ironstone..	0	6	
Lignite..	3	3	
Sandstone, clay streaks..	5	3	
Sandy clay shale...	4	9	
Soft sandstone...	38	0	
Coal...	9	0	

The relative positions of the two strong seams in the section seem to indicate that, as the lower one resembles the Drumheller seam, the upper may represent the Newcastle seam although they have not been traced continuously from either section to show the correlation. The distance between the two localities is approximately only 4½ miles so that these correlations may ultimately be tested by tracing. The upper seam is here given as being 85 feet 3 inches above the lower, as against 72 feet 6 inches at Drumheller.

Character of the Seams.

Vulcan Seam. This seam as exposed along the north bank appears to split and thin out toward the west. It is probably represented in the sections on Red Deer river above or north of the town and is mined on legal subdivision 4, sec. 23, tp. 29, range 20, at the Maple Leaf mine. As the mine is situated in the valley of Michichi creek far from the railway the coal is mined for local consumption only. The seam consists of two benches of coal separated by a parting running from 8 to 12 inches. The top bench is 18 inches thick and the bottom 2 feet, giving for the seam 3 feet 6 inches of coal. No trace of this seam is found in the Rosedale section, the top part of which is stratified clay, though the clay may be of Pleistocene age and the seam may underlie the prairie behind.

Newcastle Seam. This seam is exposed in the banks below the town and it is possible that it may be traced to the Rosedale mine. Opposite the town of Drumheller it has been opened in several places. An old entry is still to be seen on the north bank in section 10, from which, probably, the first coal was mined in the district. The seam is eroded from the flats on which the town is built. It is exposed in a small mound at the station and presumably underlies the remnants of the river plateau to the south and west of the town. It disappears beneath the river flat in the next section west and is now mined at the Newcastle mine on section 9 and in the associated mine to the south called the Alberta block. The Premier, a small mine east of the above two properties, is on this seam. The coal is fairly clean and there seem to be few rock partings, giving the seam about 4 feet 4 inches to 4 feet 8 inches of coal. It is one of the seams that vary in thickness in short distances, thus the thickness of the exposure at the Drumheller mine near the office is given as 40 inches. It is probably found in the shafts of the Stirling and Midland collieries, but as it is there about at river level it may be too wet to mine. The roof in the Newcastle mine is reported to be of a fairly hard sandstone easily supported.

Drumheller Seam. This seam, 72 feet below the Newcastle, is the thickest in the district and is in consequence the one most generally mined. The following list includes the names of the mines opened on this seam:

In the valley of the Rosebud river near Wayne station: Rosedeer and Western Commercial mines.

In the valley of Red Deer river: Star, Rosedale, Drumheller, Stirling, Midland, and Red Deer Valley mines.

As before noted the seam dips slightly northwest which is practically upstream. It is at water level about opposite the mouth of Rosebud river. At the Star mine, the farthest south, it is above the river. At Drumheller town it is well below the river, that is, it is 75 feet below the railway grade and at the mines west of the town the seam lies from 130 to 180 feet below the river bench on which the mining plants are built.

The character of the coal seam in the different mines, which were not all visited, is described by Mr. D. A. Macaulay in a paper read before the Canadian Mining Institute[1] and the following information is mainly drawn from that paper.

[1] Trans. Can. Min. Inst., vol. XVIII, 1915, pp. 322–334.

The proof of the continuity of the seam is believed to be quite apparent in the similarity of the sections found at different points, explained in the following paragraph from the paper just cited.

"While in some cases these mines are separated by a number of miles, and considerable difference is shown in the sections of the seams, roof and floor, yet there is enough similarity to lead to the conclusion that all these mines are working on the same seam. A parting which is characteristic of the seam is found in all the mines mentioned. It averages about 15 inches thick and is composed of a band of grey clay from 3 to 6 inches thick, overlaying a very hard granular coal. Between this and the good coal of the bottom bench is a band of bone about 3 inches thick. The coal in the bottom bench varies in thickness at the different mines. In those where it is thin it would not pay to remove the parting in order to mine the bottom bench; consequently at several of the mines only the top bench is worked."

Sections in the Various Mines.

In reading the following descriptions of sections in the various mines reference should be made to Figure 3.

Rose Deer Mine. The whole seam is here mined but is thinner than to the east and north. From roof to floor the distance is 6 feet 6 inches made up as follows:

	Feet	Inches
Top coal	3	0
Clay		1 to 4
Coal		6 " 8
Bone		1 " 5
Bottom coal	2 to 3	

Star Mine. The seam here is probably about 9 feet thick, but the top bench is reported by Mr. Macaulay to be the only part worked. It is 5 feet 6 inches thick including about 3 inches of clay parting 15 inches above the floor or above the granulated coal mentioned in the quoted paragraph above. The mine was opened in June 1914, and, as the railway is on the opposite bank of Red Deer river, the coal cars are transferred by an aerial tramway to the railway. The equipment allows of a shipment of possibly 200 tons per day.

Rosedale Mine. The seam is here below the river flat and is reached by a vertical shaft 40 feet deep. The distance from roof to floor is about 9 feet—the variations being mainly due to the varying thickness of the lower bench of coal.

The upper bench is not quite as thick as in the Star mine. The top coal is given as 4 feet 4 inches with a small parting about 1 foot 5 inches from the bottom. The general parting in the middle of the seam which is found over the entire area is here about as follows:

	Inches
Bone or very hard shale	1
Clay	6
Granulated coal	6
Lower bone	3

The lower bench varies from 3 feet 6 inches to 4 feet. The roof seems very stable.

Drumheller Mine. This mine is situated at the southern edge of the town of the same name. The seam, 70 feet below the surface, is reached by a slope of 20 degrees pitch. The upper bench is worked and runs to 5 feet in thickness. In this, there is sometimes a bone at the top which runs to 6 inches in thickness. The clay parting, which here is near the floor, is of a light grey colour; it is probably similar to that in the other mines and contains a large quantity of colloidal

matter. Beneath the floor there is sometimes coal and, in many places, rock. The variations in the coal in this area are of importance as the introduction of bony rock is generally at the expense of the good coal. The same condition is

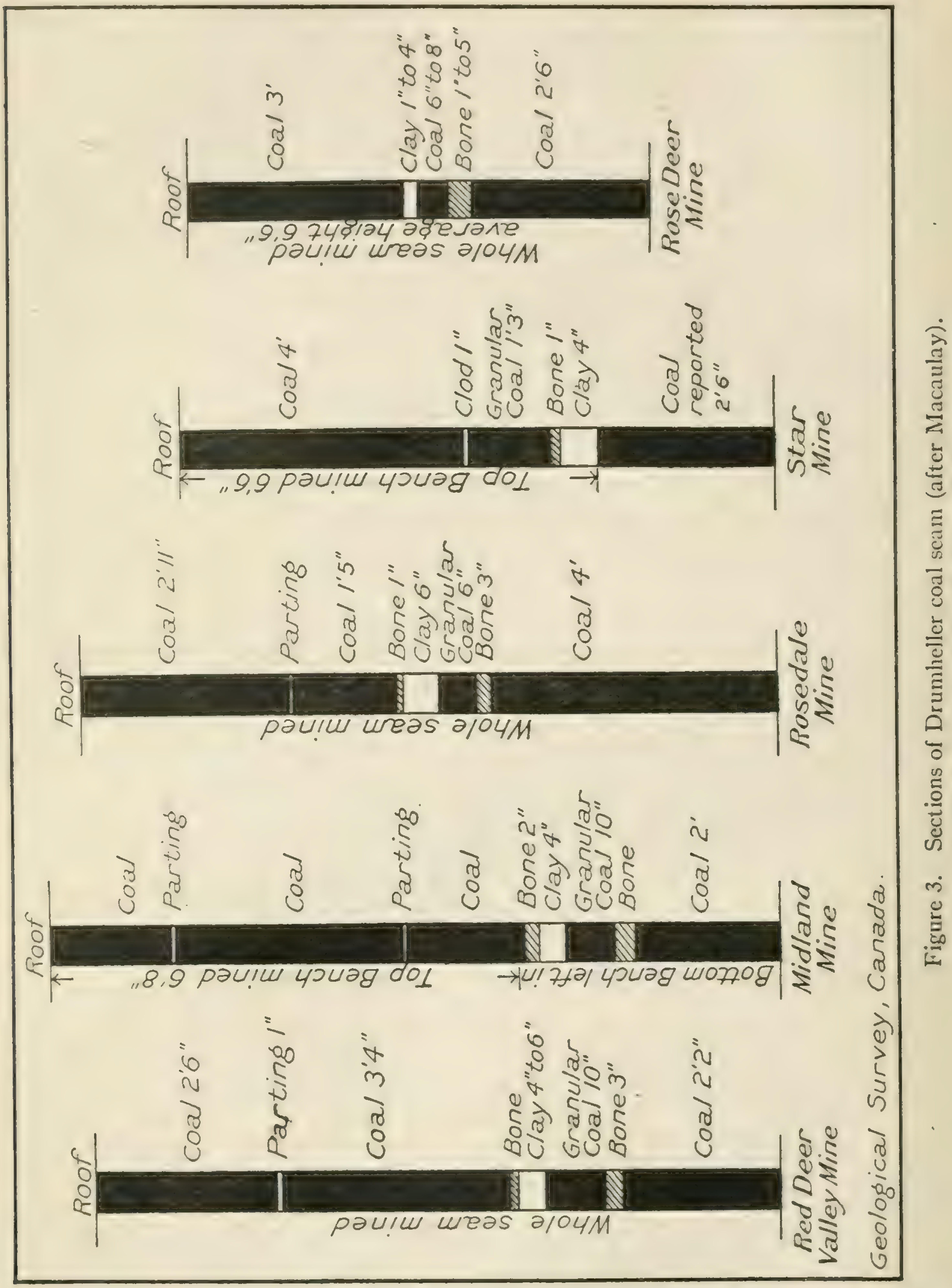
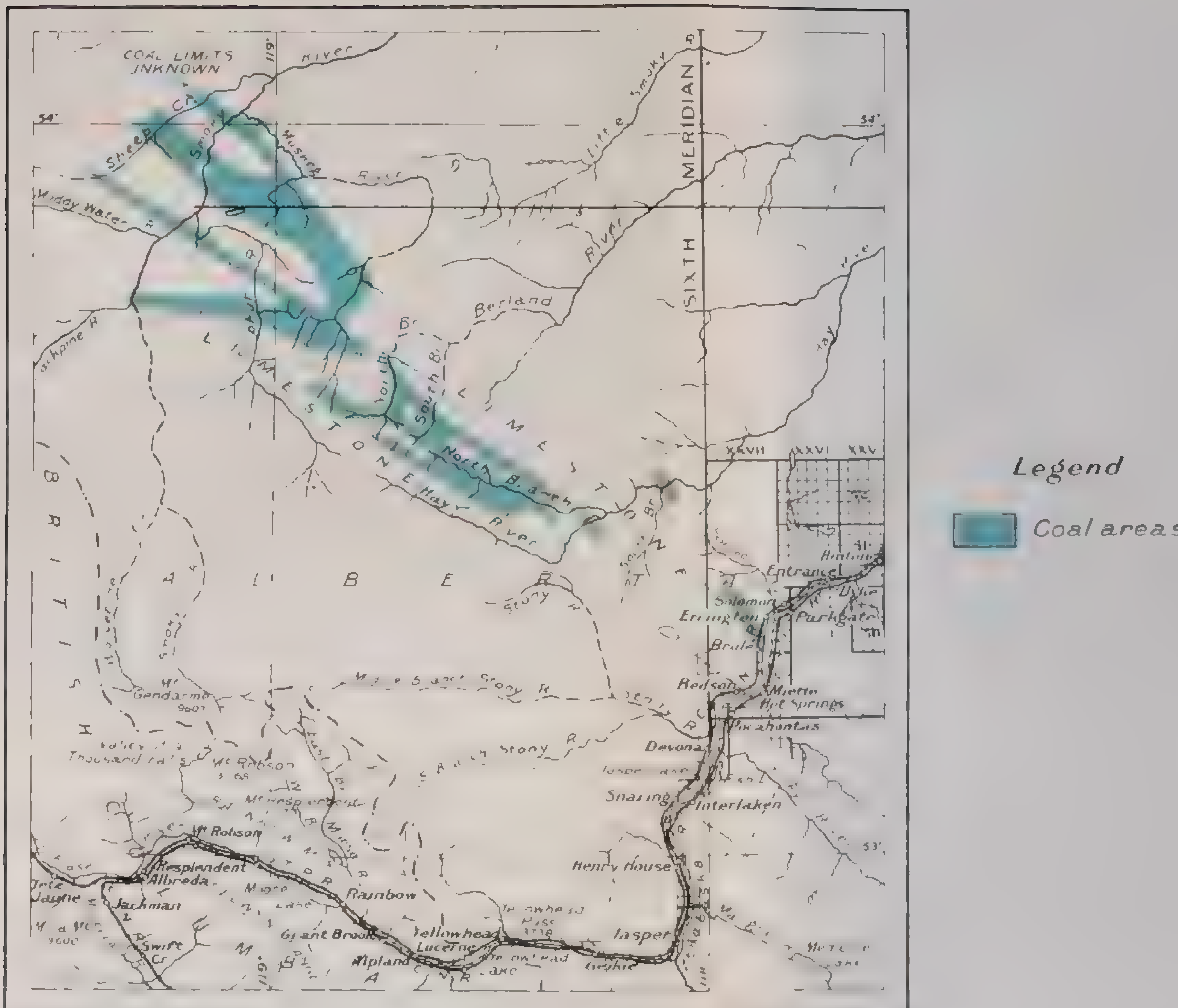


Figure 3. Sections of Drumheller coal seam (after Macaulay).

found in the two mines to the west of the town where the bony matter does not always show until exposed in the mine cars.



Geological Survey, Canada

Coal areas in the foothills between Athabaska and Smoky rivers, Alberta.

Scale of Miles

0 5 10 15 20

To accompany Summary Report by J. MacVicar, 1916

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Stirling Mine. The seam is here at about 150 feet below the river flat, and is reached by a vertical shaft. No section of this seam was given by Mr. Macaulay. It is probable that only a part of the seam is worked owing to the presence of bony coal in the lower bench.

Midland Mine. This mine is on the north bank of the river and the seam is reached by a slope of about 20 degrees. The coal is about 130 feet below the surface. The Newcastle seam was probably worked here at first and being near the river level would be wet. The present mine on the lower seam is not reported as being wet. The section of the seam as given by Mr. Macaulay is: top bench 6 feet 8 inches coal with a clod of 1 to 2 inches in the upper part, this is the part mined; beneath, forming the floor, is bone 2 inches, clay 4 inches, granular coal 8 to 12 inches; below, bone probably 3 inches, and the lower coal bench 1 foot 6 inches to 2 feet.

Red Deer Valley Mine. This mine is west of the main line of the railway and is reached by a spur from it starting from near the Newcastle mine. It is on the south side of the river in section 7, tp. 29, range 20, and is nearly 2 miles west of the railway bridge. The seam is 180 feet below the surface and is reached by a vertical shaft. Details of the mine equipment are to be found in Mr. Macaulay's paper cited above. The whole seam is extracted and consists of a top bench 5 feet 11 inches thick, with a parting of 1 inch. The characteristic division between the top and bottom benches consists of bone 2 inches, clay 4 to 6 inches, granular coal 10 inches, and bone 3 inches. The lower coal is 2 feet 2 inches thick. This gives a coal content for the seam of 8 feet 11 inches, which is probably the maximum.

Character of the Coal.

The freshly mined coal is bright and clean and in this respect resembles the coal from the Lethbridge field. Exposure to dry air dulls it and produces many shrinkage cracks, although it stands ordinary storage and shipment very well. It is not a coking bituminous coal and should be classed above a lignite. The term used generally is sub-bituminous. The mine moisture in the coal is given as being between 11 and 13 per cent, a little higher than the Galt coal of Lethbridge; but it is claimed to be lower in ash than the Galt coal.

FOOTHILL COAL AREAS NORTH OF THE GRAND TRUNK PACIFIC RAILWAY, ALBERTA.

(*John MacVicar.*)

INTRODUCTION.

During the months of June, July, August, and September, 1916, the writer carried on exploration work in the coal areas north of the Grand Trunk Pacific railway, leaving the railway at Brulé lake, Alberta. The main object of the work was to determine the geographical position of certain coal areas in the region.

The surveys made by the party are incorporated on the accompanying map. They are transit, compass, reconnaissance surveys. The Canadian Northern railway, and various companies and individuals have furnished maps and other valuable information. For this assistance the writer gratefully acknowledges his indebtedness.

LOCATION.

The area under discussion is located in the western part of the province of Alberta. From Brulé lake, in tp. 49, range 27, W. 5th mer., the area extends in a northwesterly direction to tp. 59, ranges 7, 8, and 9, W. 6th mer. The coal measures are found not to terminate there but to extend farther in a northwesterly direction. Northwest from Brulé lake as far as Hay river the coal measures are terminated on the west by the highly inclined lower and older rocks of Carboniferous age which form the outer range of the Rockies. On the east they pass under higher and newer Cretaceous strata. This outer area was not followed northward from Hay river. The area followed is that lying between the outer and the second limestone ranges which terminate the area on the west and east, the coal occupying the basin or trough-shaped area between. From Muskeg river northward the area is in front of the outer range of the Rockies, that is, the outer range is covered by the newer strata and the second range becomes the outer range.

SUMMARY AND CONCLUSIONS.

The strata throughout the district consist wholly of sedimentary rocks ranging in age from the Devono-Carboniferous to Upper Cretaceous and Quaternary.

Limestone forms the outer and second ranges of the Rockies but the rocks of the lower ridges and valleys are chiefly sandstones, shales, and conglomerates interbanded with seams of coal. The rocks are very much folded and faulted by strike faults, thus giving rise to a number of parallel bands of the coal measures. The valleys of the larger streams are bordered by stream terraces of sand and gravel.

The economic deposits are coal, gypsum, sand, and gravel. To these may be added clay, shale, and limestone.

The coal is bituminous in character and suitable for steam, metallurgical and domestic use.

At least one seam may be classed as anthracite, comparable with the best coal mined at Bankhead on the Canadian Pacific railway. This seam is in the Smoky River area. The physical qualities of this is such as in mining will give a high percentage of lump.

GENERAL CHARACTER OF THE DISTRICT.

Topography.

The district under discussion falls naturally into three topographical divisions. The southern extends from Brulé lake northward to Hay river. This is situated immediately in front of the outer range of the Rockies whose crest line exhibits a rough saw-toothed arrangement of peaks. In front of this the foothills form a succession of ridges of even crest line and elevation. At intervals these are dissected by the small transverse drainage streams that head in the outer range. Solomon creek drains the southern end of this district and flows into Athabaska river. Hay river receives a couple of small creeks from the northern end of the division.

The middle division occupies a basin-like depression between the first two limestone ranges of the Rockies. The general elevation of the basin is between 1,000 and 2,000 feet below the ranges and about 3,000 feet above the valley of Athabaska river and Brulé lake. The distance between the two ranges is from

6 to 8 miles. Traversing the middle division are well-defined ridges running parallel with the bordering ranges and resembling the foothill ridges. Hay river crosses the south end and receives its north branch which with its tributaries drain the south half of the division. The northern portion is drained by Baptiste and Muskeg rivers and their tributaries. These occupy rather small valleys that end in the second range.

The northern division exhibits a general foothill appearance. The outer range of limestone, which borders the middle division, disappears at the north branch of Baptiste river. The second range crosses Sulphur river just above the mouth of Walton creek and continues in a westerly direction up the east side of Smoky river but some miles from it. The direction of the hills is northwest. The general elevation is 1,000 to 2,000 feet lower than that farther south. Draining the area are Smoky river and its tributaries, Muskeg and Sulphur rivers, and Sheep creek. Smoky river occupies a broad and deep U-shaped valley. Muskeg river near its headwaters occupies a typical V-shaped valley which soon becomes rather broad and shallow as it winds through the hills. For the last 10 or 12 miles of its course it is in a canyon 50 to 100 feet deep. Sulphur river is in a rather narrow U-shaped valley as far as the mouth of Walton creek where it enters a canyon over 100 feet deep. This continues to its mouth. For about 10 miles above its mouth Sheep creek is in a canyon and from there up, the valley is considerably wider. Sheep creek is a stream about 100 feet wide and 2 feet deep. Muskeg river is about the same size, and Sulphur river is a stream 150 feet wide and 2 feet deep at low water. Smoky river is a stream of considerable size and with a swift current. It averages about 200 feet in width and is too deep to ford except at a few points and then only during low water.

CLIMATE AND VEGETATION.

The summers are not marked by high temperatures. The winters are characterized by clear air and sunshine with the absence of high winds. The climate in the vicinity of Smoky river does not differ greatly from that at Brulé lake on Athabaska river. Chinook winds prevent the accumulation of snow along these rivers so that stock can graze out the whole winter. The rainfall is ample and the growth of grass and peavine is luxuriant. For the most part the hills are heavily forested with a good stand of spruce and jack-pine. Large areas have been destroyed by fire but these are now covered with a growth of small trees. Along Hay river particularly, the hills with southern exposure are bare of forest and grassed to the top. The principal trees are varieties of spruce, balsam, pine, aspen, and cottonwood.

FAUNA.

Game is plentiful throughout the district. Moose, caribou, deer, mountain sheep, and goat are to be seen, also black and grizzly bear. Large catches of fur comprising fox, lynx, coyotes, rabbit, martin, weasel, fisher, and otter are yearly brought out by the trappers.

Fish of the trout species are caught in most of the streams. They are very plentiful in lac A la Passe and Muskeg river.

COMMUNICATION.

The Forestry Department has completed splendid pack trails to Grande Cache. One runs up Hay river and down Sulphur river and another runs for about 30 miles along the front of the mountains as far as Muskeg river and then

along it past the Grande Cache lakes to meet the trail down Sulphur river at Grande Cache. For winter freighting a sleigh trail runs up Solomon creek to Hay river and thence up it to near the summit. Another sleigh trail follows the outer pack trail above mentioned to Grande Cache. Less important trails intersect the district.

The Canadian Northern railway has made surveys for a branch line up Solomon creek to Hay river and up Hay river to near its source.

GENERAL GEOLOGY.

The surface formations throughout the area to which this report relates consist of sedimentary rocks. The rocks represent Devono-Carboniferous, Jura-Trias, Cretaceous, Tertiary, and Quaternary systems. Throughout most of the field the rocks dip at a relatively high angle to the southwest. As a result of the steep dips the rocks are fairly well exposed and the major structures are somewhat pronounced.

Table of Formations.

Quaternary	River and Glacial drift.
Upper Cretaceous	Belly River (?), Benton, Dakota.
Lower Cretaceous	Kootenay.
Jura-Trias.	
Devono-Carboniferous.	

Description of Formations.

Devono-Carboniferous. Limestones of this formation are exposed along the axis of the first and second ranges of the Rocky mountains. Just west of Brulé lake, Bullrush mountain rises to a height of about 7,000 feet above sea and about 4,000 feet above Brulé lake. It is a prominent landmark visible for long distances. The strike of the rocks in the slightly overturned anticline is north 65 degrees west and the dip is to the southwest. Mr. McEvoy[1], for these rocks, gives the following section. It was measured on Folding mountain just across the lake.

Section on Folding Mountain.

	Feet
Grey quartzites	200
Black carbonaceous shale	60
Dark flaggy limestone	100
Yellowish, fine-grained, siliceous shales with calcareous shales and some calcareous sandstone	500
Fine-grained, grey and yellowish limestone, highly siliceous with a few bands of dark quartzite	500
Covered	300
Fine-grained, blue limestone	500+
	2,160

The outer range as far as Hay river is made up of pure as well as cherty limestone. The latter contains a large amount of siliceous material. In weathering, the limestone, being soluble, is gradually carried away leaving the exposed surface rough with chert which in places is a characteristic feature of the rock. The colour ranges from dark grey to blue. The strata is in three folds and these folds form the crests of the three ridges composing the outer range.

Jura-Trias. The strata between the Devono-Carboniferous limestones and the Kootenay coal measures comprise thin-bedded sandstones and dark shales, the latter often passing into hard slaty shales. Fossils are scarce and no attempt was made to separate them.

[1] McEvoy, James, "Yellowhead Pass route", Geol. Surv., Can., Ann. Rept., vol. XI, 1898, pt. II, p. 28.

Kootenay. The coal measures consist of sandstone, shale, slate, and beds of coal from a few inches in thickness up to 100 feet or more. The prevailing colour of the sandstone and shale is grey. Beds of conglomerate occur within the coal measures, a notable one being at the base of the measures. Except for a portion at the top and bottom, the coal beds are pretty well distributed through the measures. The intervals separating the coal beds vary from a few feet to a few hundred. Probably the most striking and conspicuous feature of the Kootenay is the conglomerates. Good exposures of these are to be found throughout the area and show them to be remarkably similar in appearance and composition. The conglomerate at the base of the measures is made up of pebbles, the largest about the size of a hen's egg. In most places smaller pebbles comprise most of the rock and range in size down to that of a pea. There is just enough finer sand material to cement the whole together. The prevailing colour is grey but other colours are scattered through, such as green, blue, and black. A hundred feet is a common thickness for the conglomerate, but in places it is much greater.

Dakota. This formation lies conformably upon the Kootenay. It is essentially a sandstone formation and widely distributed in the area. On a fresh fracture the colour is usually grey to greenish, weathering to a reddish or brown. The grain varies from fine to coarse, passing in places into a conglomerate. It is of great thickness, probably not less than 3,000 feet, and comparatively hard.

Benton. This formation rests upon the Dakota conformably. It consists of a great thickness of dark marine shales. It is possible that rocks of Niobrara age are also included. On account of its soft, yielding nature it is mostly found in the valleys and depressions. Fresh exposures may be seen where the corrasion of the streams is rapid enough to remove the weathered portion and bring the solid rock to the surface. Many such places are to be found on the principal streams draining the district. When exposed for a time to the weather these shales become fissile, crumble to small pieces, and ultimately become clay. Bands of nodular ironstone occur in places, at others bands of sandstone. Iron rust is abundant in some localities while in others a white encrustation forms on the rock.

STRUCTURAL GEOLOGY.

Structurally the district is simple in theory though complicated enough in detail. Briefly it may be described as a series of anticlinal and synclinal folds running in a northwesterly direction across the area.

The southern portion of the coal area is comprised in the principal anticlinal fold forming the first ridge of hills in front of the outer limestone range. The axis of the fold follows the crest of these hills. A fault along the south fork of Solomon creek, with a downthrow of the strata to the north of that stream, conceals the coal measures as far as Hay river where they are exposed in the eroded valley.

In the middle coal area the structure is quite simple, consisting of a succession of folds with dips ranging from 20 to 70 degrees. The folds are not all regular, however, as the larger ones are often corrugated by smaller and shorter flexures. Erosion has denuded the crests of some of the anticlines, somewhat obscuring the structure in places and the strike faults that traverse the district further obscure the structure.

In the northern division, the great waves into which the originally horizontal measures of the region were thrown reach their maximum height along the southern edge of the field. Here the north dipping strata have been tilted up to a perpendicular and overturned position. To the north and east the plication of the measures lessens, the steeply dipping sides giving place to more gentle

dips of 20 to 30 degrees. Strike faults and the lesser flexures are to be found here also.

ECONOMIC GEOLOGY.

The mineral resources of the area are somewhat varied, the principal one being coal. Gypsum deposits occur on Deer creek near the divide between Hay and Snake Indian (Stony) rivers. Sand and gravel can be obtained at varied intervals. Limestone is common and may be utilized in time for lime and cement. It is probable that some of the many shale beds will prove valuable in the clay and cement industries.

Coal.

Throughout the area coal occurs in the Kootenay series of the Lower Cretaceous rocks. The economic coal seams are found in the middle of the series, the top and bottom being barren. At a number of widely separated places considerable prospecting has been done by claim owners to disclose the number and thickness of the coal seams. The following are the principal ones.

Mines. The Brulé Lake Coal Company have the only working mine in the district discussed in this report. Considerable development work has been done on their property. The following section was furnished by the company. It is measured in descending order.

Section on the Property of the Brulé Lake Company.

	Feet
Conglomerate	———
Sandstones and shales about	700
Coal	7
Sandstones and shales	400
Coal	12
Sandstones and shales	120
Coal	7
Sandstones and shales	200
Coal	7
Sandstones and shales	300
Coal	7
Sandstones and shales	100
Coal	14
Sandstones and shales	600
Coal	7
Sandstones and shales about	1,200
	3,681

Prospects. Along Solomon creek a number of prospects were visited. Considerable surface work has been done to determine the thickness and number of coal seams. In some cases short tunnels were run. These prove the measures to extend northward as far as the south branch of Solomon creek.

On the north branch of Hay river a number of coal claims are staked upon which some surface work has been done to prove the thickness and number of the coal beds. A number of beds are exposed: one of great thickness contains a bed of good coal about 40 feet in thickness. On the south branch of Baptiste river, coal claims were visited showing good coal exposures. On the north branch of the Baptiste and on Muskeg river coal exposures were seen, the measures

being the northward extension of those on Hay river. On Sulphur river, on Smoky river, and on Sheep creek, claims were visited upon which some surface work was done and a number of good coal seams of workable width exposed. On the Isenberg claims on Smoky river considerable prospecting has been done. Tunnels have been driven on five of the seams, 100 feet or more into the hillside. In the table on page 92 is given the results of the anaylsis of the average sample taken. The following is a partial section of the measures on these claims in descending order:

Section on the Isenberg Claims.

	Feet
Sandstone and shale	600
Coal	3·6
Sandstone and shale	175
Coal	3·6
Sandstone and shale	150
Coal	12
Sandstone and shale	20
Coal	4
Sandstone and shale	1,200
Coal	4
Sandstone and shale bottom of the measures concealed	
	2,172

Analyses of Coals from Isenberg Claim, Smoky River.

Thickness of seam, feet	Moisture	Volatile matter	Fixed carbon	Ash	B. T. U.	Remarks
8	0·5	19·6	63·4	16·5	12,715	From the tunnels.
9	0·4	21·1	69·8	8·2	14,040	" " "
17	1·1	18·4	74·0	6·5	14,100	" " "
12	0·4	18·5	69·4	11·7	13,600	" " "
9	0·3	19·8	73·0	6·9	15,070	" " "
7½	1·3	12·5	78·2	8·0	13,862	
7	0·9	13·4	81·7	4·0	14,706	A number of 50 lb. samples carefully taken for coking trials from some of these seams, were tested in the coke ovens at Fernie, B.C., and found to yield an excellent coke.
7	2·9	14·8	80·1	2·2	13,800	
10	1·7	18·1	73·9	6·3	13,990	
15	1·6	19·4	71·6	7·3	13,255	
5	0·9	14·7	82·5	1·9	14,987	
10	0·7	22·6	72·3	4·4	14,800	
7½	0·5	18·5	72·8	8·2	14,300	
10	0·7	15·3	76·2	7·8	13,913	
13	0·5	18·4	73·5	7·6	14,220	
9	1·0	20·3	71·9	6·7	14,160	

Approximate position sec. 15, tp. 58, range 8, W. 6th mer.
Collector John MacVicar; analyst Mr. Graham, provincial laboratory, Edmonton.

Analyses of Coals from Foothills North of Grand Trunk Pacific Railway.

Lab. No.	Thickness of seam Feet	Locality	Approximate position				Analysis of coal as received				Calculated for dry coal at 105°C.			Fuel ratio	Coking qualities
			Sec.	Tp.	R.	West of mer.	Moisture	Volatile matter	Fixed carbon	Ash	Volatile matter	Fixed carbon	Ash		
889	Small	Bartholemew claim near Brulé lake.	17	50	28	5	2·2	15·3	63·8	18·7	15·6	65·3	19·1	4·15	Non-coking.
890	18	Errington claim, Hay river.	24	52	4	6	1·1	24·0	58·6	16·3	24·3	59·2	16·5	2·45	Forms small lumps of dense hard coke.
891	...	Errington claim, Hay river.	27	52	4	6	2·9	23·6	56·9	16·6	24·3	58·6	17·1	2·40	Non-coking.
892	100	MacConnachie claim, Hay river	2	53	5	6	1·9	26·2	58·8	13·1	26·7	59·9	13·4	2·25	Non-coking.
893	...	Abbott claim.	4	57	7	6	1·1	23·0	70·6	5·3	23·3	71·4	5·3	3·05	Forms good coke.
894	...	Campbell claim, Sheep creek.	9	58	9	6	1·3	17·4	78·2	3·1	17·6	79·2	3·2	4·50	Non-coking.
895	...	Moberly claim, Sheep creek.	4	58	9	6	1·3	17·0	78·7	3·0	17·2	79·8	3·0	4·65	Non-coking.
896	...	A. Joachim claim, Smoky river.	24	56	9	6	1·3	16·9	79·3	2·5	17·1	80·3	2·6	4·70	Non-coking.
897	17	Isenberg claim, Smoky river.	15	58	8	6	1·4	19·5	76·1	3·0	19·8	77·2	3·0	3·90	Agglomerates slightly.

Collector, John MacVicar; analyst, J. H. H. Nicolls, Department of Mines.

COAL MINES OF WEST CENTRAL ALBERTA.

(*J. S. Stewart.*)

INTRODUCTORY.

During the past summer the writer made a geological investigation of several coal mines in the foothills of west central Alberta, which have hitherto not been reported upon in detail by the Geological Survey. Samples of coal were taken at the various mines and these are now being analysed by the fuel-testing division of the Mines Branch and the results will be published later.

ACKNOWLEDGMENTS.

The officials at the several mines visited helped along the work by cheerfully furnishing all the information and maps available and in several cases even giving practical aid in the field. For this and many other favours received the writer is much indebted and wishes to express his thanks.

BRAZEAU COLLIERIES.

The Brazeau collieries are located at Nordegg, Alberta, on north Saskatchewan river. The mines are made accessible by a branch line of the Canadian Northern railway which runs west from Settler to Nordegg, the distance by rail being about 178 miles.

This coal basin lies just west of the Brazeau range, which here forms the front range of the Rocky mountains. The structure of this range is anticlinal. The west limb, upon which the Brazeau collieries are located, has a dip of about 12 degrees. The east limb on the other hand is characterized by steep dips and is overturned and broken by a fault of considerable displacement. Although some of the Kootenay coal measures occur on the faulted eastern limb of the anticline, the coal seams are likely to be too much crushed and broken to be workable.

The rocks which compose the Brazeau range are mainly limestones. The cross section through the anticline along the railway reveals a thickness of about 1,750 feet of Palæozoic limestones with less amounts of quartzite and calcareous shales. These beds include both Devonian and Carboniferous strata. Overlying this, there are about 900 feet of shale with several limestone beds which, on the basis of a few belemnite fossils, are referred to the Fernie formation (upper Jurassic); some of the lower shale beds, however, may be Triassic, as shales of this age are believed to occur to the west and also south of this section.

The Fernie formation is overlain by the Kootenay, which here consists of shales, sandstones, and coal beds with a few lenticular beds of limestone. The deposits are of continental origin, the fossils being mainly fern-like plants; but, a few horizons carry a freshwater molluscan fauna. Near the base of the formation there is a thick bed of conglomerate, the base of which is not exposed; the contact with the Fernie formation lies somewhere between the conglomerate and a belemnite-bearing limestone about 400 feet below the surface.

The coal-bearing strata belong to the Kootenay formation, but the rocks of the Kootenay and formations immediately overlying are rarely exposed, being concealed by thick deposits of glacial drift.

The following notes relating to the early development of the field are extracted from the Summary Report of 1913.[1]

[1] Dowling, D. B., Geol. Surv., Can., Sum. Rept., 1913, pp. 150, 151.

"The section secured by the excavations as given by the engineer's measurements, is as follows, in descending order:

Section at Brazeau Collieries.

	Feet	Inches
Barren measures	60	0
Coal seam No. 5	7	2
Barren measures	120	0
Coal seam No. 4	2	6
Barren seam	106	0
Coal seam No. 3	15	11
Barren measures	123	0
Coal seam No. 2	7	9
Barren measures	85	0
Coal seam No. 1	4	2
Black shales and sandstones, about	100	0
	631	6

"Five seams with an aggregate thickness of 37 feet 6 inches of coal in 631 feet 6 inches of measures.

"Seam No. 1 (4 feet 2 inches) was not considered of sufficiently high grade coal to warrant its present exploitation.

"Seam No. 2 (7 feet 9 inches) has a roof of shale in thick benches and is of satisfactory strength. In the tunnel, the coal is found to be very friable and as the surface burden is light for a long distance, the surface water is draining through the seam and the coal is very much damaged thereby. A higher grade coal may be obtained at a greater distance from the surface. At a distance of 135 feet from the mouth of the tunnel the coal was still friable and would produce a large percentage of small coal. An analysis by the Milton Hersey Company, of a sample taken across the full seam at 135 feet in the tunnel, gave:

Analysis of Brazeau Coal.

Moisture	0·44 per cent.
Volatile combustible matter	17·01
Fixed carbon	69·12
Ash	13·43
	100·00

Coke, dull but firm; heating value, 13,202 B.T.U.; sulphur, 0·49 per cent.

"Seam No. 3 (15 feet 11 inches) is usually accompanied by a band of shale commonly found within a foot or so of the roof. It occasionally disappears and again is found with greater thickness. The lower part is the best coal, and may be separated from the upper shaly part. Analyses of samples across a thickness of 13 feet 6 inches from the floor are as follows:

Analyses of Brazeau Coal.

	Upper 6 feet 6 inches which is below shale band.	Lower 7 feet 0 inches to floor of seam.
Moisture	0·63	0·45
Volatile combustible matter	17·97	17·63
Fixed carbon	66·00	69·92
Ash	15·40	12·00
	100·00	100·00
Sulphur	0·55	0·49
Calorific value	12,834 B.T.U.	13,426 B.T.U.
Coke	Dull but firm.	Dull but firm.

"Seam No. 4 (2 feet 6 inches). This seam is considered too thin to be worked at present.

"Seam No. 5 (7 feet 2 inches). The coal in this seam proved very high in ash, consequently very little excavation was made on it."

The following additional analyses of Brazeau coal were received from R. S. Foote. The samples were taken from cross sections in the Nordegg mine, in September, 1914.

Analyses of Coal from Nordegg Mine, Brazeau Collieries.

Location	Moisture %	Vol. mat. %	Fixed car. %	Ash %
Face of main level No. 3 seam	0·63	15·02	68·88	15·47
Face of dip level No. 3 seam	0·80	14·02	69·79	15·39
Face of counter level No. 3 seam	0·61	14·02	69·02	16·35
Average No. 3 seam	0·68	14·35	69·23	15·77
Face of main level No. 2 seam	0·58	14·74	68·43	16·25
Face of No. 1 counter level No. 2 seam	0·72	14·03	70·67	14·58
Face of No. 2 counter level No. 2 seam	0·56	14·83	73·33	11·28
Average No. 2 seam	0·62	14·54	70·81	14·03

Sample being equal mixture of six face samples.

Sulphur .... 0·56%

B.T.U. 12,540

Chemical Analyses of Ash.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
70·04%	27·22%	Trace	3·30%	Trace

The prospecting by trenches, pits, and tunnels has been supplemented by two diamond drill holes. The cores had been carefully boxed and labelled by the company so that the writer was able to examine them and construct complete logs. The following is the log of the deeper hole and shows the character of the strata associated with the coal beds.

Log of Drill-hole No. 2, Brazeau Collieries.

Depth in feet. *Strata.*

0–6. Soil.
6–12. Shale.
12–21. Shale, soft grey.
21–29. Sandstone.
29–36. Grey shales.
36–53. Sandy shales, greenish grey, extremely friable.
53–64½. Mostly shale, friable, greenish grey in colour. The lower 2 feet is more solid and better cemented.
64½–83. Sandy shale, dark greenish grey.
83–92. Sandy shale, greenish grey, friable.
92–94. Sandy shale, greenish grey, friable.
94–108. Shaly sandstone, fine-grained, dark grey with a little carbonaceous material.
108–111. Carbonaceous shale followed by 3 inches of *coal.*
111·6–118·6. Carbonaceous shale followed by another 3 inches of *coal.*
118·6–123. Carbonaceous shale; from 114 to 118 feet these shales yielded several well preserved fossil plants.
123–132. Shaly sandstone, dark grey carbonaceous, with plant material.
132–135. Sandy shale, black carbonaceous.
135–140. Sandstone, grey, fine-grained, comparatively light in colour.
140–144. Sandy shale, firmly cemented, yields a solid core, dark grey in colour.
144–149. Sandstone, grey, with small amount of carbonaceous material.
149–153½. Sandstone, grey, very fine-grained.

Depth in feet.

153½–161½. Shale, dark grey, very friable, contains considerable carbonaceous material.
161½–173½. Shale, black and carbonaceous, contains much black shiny vegetable remains.
173½–180½. Shale becomes more massive, harder, and contains less carbonaceous material.
180½–194. Shaly sandstone, fine-grained, slightly carbonaceous.
194–206. Shale, dark grey.
206–213. Sandstone, grey, fine-grained.
213–224. Sandstone, grey with numerous carbonized plant fragments.
224–232. Sandstone, comparatively light grey, fine-grained, contains a small amount of carbonaceous matter.
232–235. Shale, dark grey, friable, carbonaceous.
235–238. Sandstone, grey, fine-grained, dark in colour with numerous small specks of coaly matter ; the rock is firm and hard, yielding a solid core.
238–240. Sandy shale, carbonaceous.
240–242. Sandstone, grey, medium-grained.
242–251. Sandstone, grey, fine-grained, somewhat shaly at about 246 feet.
251–256. Grey shale.
256–257½. Sandstone, fine-grained, one-quarter inch coal.
258–261. Shale, dark grey, friable.
261–263. Shale, dark grey, coaly and friable.
263–268. Sandstone, black, fine-grained and shaly, and carbonaceous.
268–283. Shale, carbonaceous, hard and massive in many places, with many small plant impressions throughout, becomes sandy at about 280 feet.
283–284. Coaly shale.
284–285. *Coal.*
285–289·6. Black coaly shale, very friable.
289½–294½. *Coal.*
294½–303. Shale, dark grey, friable, quite sandy, almost sandstone in places.
303–318. Sandstone, shaly, dark grey, very fine-grained.
318–332. Sandstone, dark grey, fine-grained, hard and massive, yielding a long solid core, shaly toward top and bottom.
332–335. Sandstone, dark grey, fine-grained.
335–346. Sandstone, grey, medium-grained.
346–363. Sandstone, grey with numerous small specks of carbonaceous matter, medium to fine-grained, yields long solid cores.
363–377. Sandstone, hard, grey with considerable carbonaceous matter and a few coaly streaks, fine-grained.
377–383. Sandstone, fairly coarse, well cemented and hard. Carbonaceous with coaly matter, otherwise the sandstone is pretty clean.
383–398. *Coal.*
398–402. Shale, sandy, black, and carbonaceous.
402–403. Shale, carbonaceous, containing plant remains.
403–404. Shale, black, carbonaceous, and friable.
404–408. Sandstone with plant remains, fine-grained, dark grey.
408–415. Shale, sandy, black, carbonaceous, friable.
415–418. Shale, black, carbonaceous with plant remains, somewhat fissile.
418–431. Black shales, very friable, carbonaceous and coaly for about 2 feet (418 to 420).
431–448. Shale, dark grey, extremely friable, with much carbonaceous, coaly matter at about 446 feet.
448–451. Sandstone, fine-grained, dark grey, carbonaceous.
451–455. Shale, sandy, highly carbonaceous and black, containing many plant fragments.
455–462. Sandstone, fine-grained, carbonaceous, dark grey.
462–481. Sandstone, grey, carbonaceous with numerous coaly plant impressions, fine-grained.
481–491. Sandstone, fine-grained, carbonaceous, becomes shaly toward 490 feet passing into coaly shale and coal.
491–499. Shale, black to dark grey.
499–506. *Coal.*
506–515. Sandy shale, dark grey with considerable carbonized plant remains.
515–533. Shale, black and extremely friable, sandy, and carbonaceous.
536–548. Shale, sandy, dark grey somewhat greenish in places, rather friable.
548–551. Black shale, friable, carbonaceous.
551–555. Sandy shale, hard, dark grey.
555–563. Sandstone, fine-grained, with numerous small fragments of carbonized plant material.
563–568. Shale, dark grey carbonaceous and firm, two small specimens of plants were collected.

Depth in feet.

568–572. Sandy shale, grey, fine.
572–576. Shale, carbonaceous and extremely friable.
576–578. Shale, sandy, dark grey, fairly massive, and hard, also,somewhat carbonaceous.
578–581. Shale.
581–584. Black shale.
584–585. *Coal.*
585–589. Sandstone, dark grey, carbonaceous.
589–592. Carbonaceous shaly sandstone.
592–593. *Coal.*
593–595. Carbonaceous shale.
595–596. *Coal.*
596–597. Shale, dark grey.
597–604. Sandstone, grey, medium to fine-grained.
604–608. Shale, dark grey, rather friable with a small amount of carbonaceous matter.
608–617. Grey sandstone.
617–631½. Mainly dark grey sandy shales, fairly fissile and becoming more sandy near 631 feet.
631½–643. Shale, firm, calcareous, yielding a solid hard core.
643–660. A rapid alternation of dark grey sandy shales and shaly sandstones, all fine-grained.
660–670. Sandstone, grey, hard, and yielded a long firm core.
670–681. Carbonaceous shales, sandy.
681–699. Sandy shale, black and grey, highly carbonaceous apparently due to plant material (no fossils noted).
699–717. Black carbonaceous shales, coaly about near 699 feet.
717–723. Black carbonaceous shales, very friable, become calcareous near 723 feet and contain a few molluscs.
723–729½. Carbonaceous shales with bands highly calcareous, in places almost limestone; the fracture along the bedding is commonly black and glistening.
729½–739. Shale, calcareous, carbonaceous, somewhat fissile; contains plant and molluscan fossils.
739–757. Shale, carbonaceous, fairly fissile, contains a considerable number of bivalves at about 746 to 750 feet.
757–777. Black shales, contain small bivalves about 760 to 763 feet.
777–782. Black sandy shale.
782–789. Shaly sandstone, fine-grained, black, and carbonaceous.
789–807. Mainly black friable shales with a little sandstone near the base. The shales contain numerous small fragments of shells and small pieces of pyrite.
807–811. Black siliceous shale, rich in fossil molluscs from 809 to 811 feet, bivalves gastropods.
811–813. Sandstone.
813–817. Shale, grey and carbonaceous.
817–820. Sandstone.
820–827. Shale, carbonaceous, containing numerous small bivalves.
827–833. Carbonaceous limestone, also containing numerous small bivalves.
833–843. Calcareous sandy shale, carbonaceous, yields a fairly solid core, many fragments of shells.
843–846. Sandstone, dark grey, carbonaceous, fine-grained.
846–849. Shale, calcareous, carbonaceous, hard, and massive; fossil plants and casts of molluscs.
849–851. Coaly shale.
851–856. Sandstone, fine, hard, becomes shaly and carbonaceous toward 856 feet.
856–860. Grey shale.
860–863. Sandstone.
863–874. Dark grey shale.
874–876. Carbonaceous shale, contains a few molluscs.
876–891. Mainly fine-grained sandstone, carbonaceous, with both plant and animal remains.
891–892½. Black shale with molluscan remains.
892½–902½. Black shale, well cemented and fissile, almost the entire thickness of 10 feet is highly fossiliferous, containing numerous gastropods and small bivalves which show concentric striæ.
902½–906. Black shale with a few bivalves.
906–925. Shale, calcareous, and limestone, mainly the latter, colour of rock mostly dark grey.
925–933. Shale, black, carbonaceous and somewhat fissile.
933–945. Sandstone, shaly, fine-grained, dark grey.
945–946. Carbonaceous shale, sandy, black, plant remains.

Depth in feet.

946–960. Mainly sandstone, dark grey, fine-grained, carbonaceous in the more shaly beds.
960–970. Shale, extremely friable and crumbly, carbonaceous.
970–972. Ashy grey, friable, clay shale.
972–974. Black shale with coaly matter.
974–982. Sandy shale, becoming practically a fine sandstone near 982 feet, dark grey in colour.
982–988. Sandy shale, carbonaceous.
988–990. Arenaceous limestone.
990–1,001. Arenaceous limestone.
1,001–1,010. Sandstone, grey, fine-grained, firmly cemented, dark in colour.
1,010–1,012. Shale, black and carbonaceous.
1,012–1,015. Sandstone, fine-grained, shaly, dark grey.
1,015–1,018. Sandstone, fine-grained, calcareous, and carbonaceous.
1,018–1,025. Sandstone, fine-grained, black and highly carbonaceous, hard and well cemented.
1,025–1,026. Sandstone, very fine, carbonaceous.
1,026–1,034. Sandstone, medium-grained, fairly light grey, very hard, and contains much pyrite.
1,034–1,040. Sandstone, hard, dark grey, contains much pyrite, also is inclined to be more friable, finer and shaly.
1,040–1,049. Limestone, firm, hard, shaly, beginning and ending with rather friable calcareous shale.
1,049–1,054. Carbonaceous shale, black, contains numerous plant remains, small parallel veined leaves.
1,054–1,059. Dark grey shale.
1,059–1,060. Calcareous shale.
1,060–1,065. Carbonaceous shale, fairly massive, calcareous near top.
1,065–1,069. Shale, black, carbonaceous, becomes practically a limestone at about 1,067 to 1,068 feet.
1,069–1,077. Mainly a fine-grained sandstone, dark grey, contains numerous plant fragments.
1,077–1,090. Hard, fine-grained sandstone with a small amount of carbonaceous matter.
1,090–1,096. Sandy shale, dark grey, yields a solid core.
1,096–1,100. Shale, dark grey, extremely friable.
1,100–1,117. Mainly sandy shale, extremely friable, the core being in crumbs, small amount of carbonaceous material, colour, dark grey.
1,117–1,120. Shale, black, carbonaceous, very friable and crumbly.
1,120–1,131. Sandstone, dark grey, fine-grained, shaly but yields a fairly solid core.
1,131–1,141½. Sandstone, grey, very fine-grained, contains a few fragments of fern fronds at about 1,134.
1,141–1,158. Sandstone, dark grey, carbonaceous, fine-grained.
1,158–1,170. Sandy shale, dark greenish grey, extremely friable.
1,170-1,183. Shale, dark grey to black, slightly carbonaceous.
1,183–1,190. Sandstone, fine-grained, becoming medium to coarse-grained near 1,190 feet.
1,190–1,200. Shaly sandstone, hard, fine-grained, carbonaceous, but without preserved remains.

The general dip of the beds is about 12 degrees toward the southwest. The dip of the massive competent beds is quite regular. The shales show local variations in places.

The log, however, does not show the true thickness of the coal seam as the coal is extremely friable and does not yield a core. In the course of prospecting the company have found five coal seams, only two of these, however, are worked. These seams are known respectively as No. 2 and No. 3. No. 2 seam is the lower and is about 7 feet thick on the average. No. 3 seam is about 15 feet thick.

Development work on No. 2 seam has penetrated over 4,000 feet from the tunnel mouth and on No. 3 seam it has reached 3,500 feet from the entry. At the time visited, this colliery was shipping 1,200 to 1,500 tons of coal a day.

SAUNDERS CREEK COAL MINE.

Saunders Creek coal mine is located on the Canadian Northern Railway coal branch, about 18 miles east of Nordegg. The railway here follows the valley of Saskatchewan river and in many places the cuts in the hillside reveal good

rock exposures. The country east of the front range is rolling and covered with a growth of small timber; except along the rivers and creeks, outcrops of bed-rock are rare. In the vicinity of Saunders mine, the strata dip eastward at an angle of about 5 degrees and the general strike is about 45 degrees west of north. In the mine itself, small local undulations produce slight variations from the general dip. The dip flattens toward the west and steepens toward the east. The series of rocks exposed in the vicinity of the mine consist of sandstones and sandy shales, carbonaceous shales, and coal beds. Most of the sandstones are poorly cemented and break easily, and the shaly beds are very friable. The prevailing colour of the sandstones is light grey, and that of the shales light grey to dark brown. Plant remains in the form of stems and leaves, like those of modern deciduous trees, are very common and pieces of tree trunks up to one foot in diameter were also observed. The plants suggest an Upper Cretaceous and probable Edmonton age for the series, but no diagnostic fossils were obtained.

The prospecting has revealed two coal seams, an upper one about 12 feet thick and a lower one 5 feet in thickness, the stratigraphic interval between the two seams being 150 feet. The thick upper seam contains several thin shale partings which make the coal too dirty to be marketable. The lower 5-foot seam is, however, a clean, bright coal and has earned a good reputation as a domestic fuel. The workings on this seam extend about 720 feet from the entry. The output at the time visited in July was about 20 tons per day.

PACIFIC PASS COLLIERY.

The Pacific Pass colliery is located at Lovett and is tapped by a branch of the Grand Trunk Pacific railway which leaves the main line near Edson and runs in a southwesterly direction. The region in the vicinity of the mine is characterized by several low parallel ridges with intervening valleys in which flow small tributary streams. Ridges and valleys alike were at one time forested but fires of recent years have consumed the tree growth more or less completely over large areas.

The strata in the vicinity of the mine have a dip of about 12 degrees toward the southwest; the general direction of strike being about 50 degrees west of north. The general structure is anticlinal with the crest about a mile northeast of Lovett, the mines being located on the western limb. Superposed upon this structure there are, however, some minor folds and small faults. It is seldom that these small faults can be detected on the surface but they commonly form serious obstacles in the mining operations. No good section of the strata is exposed around Lovett. Outcrops occur near the mine and along the railway between Lovett and Coalspur, and these show a series of sandstones, shales, and coal beds. Some of the coal beds are very thick and have numerous partings of friable, black shale which makes the coal too dirty to be marketable. The sandstones and shales contain plant remains in many places, which indicate an Upper Cretaceous age, but the exact horizon has not been determined. The following columnar section was obtained from the log of two drill-holes bored by the company, in the vicinity of the workings.

Log of Drill-hole at Pacific Pass Colliery.

Strata	Thickness Feet	Thickness Inches
Sand and gravel	4	
Grey shale	3	
Grey sandstone	25	6
Grey shale	13	5
Dirty *coal*	1	
Coaly shale	4	
Coal "silkstone seam"	14	
Clay shale	19	
Coal	1	
Carbonaceous shale	2	
Coal	4	
Clay shale	27	6
Sandstone	20	
Dark shale	27	
Grey sandstone	11	6
Clay shale	3	6
Coarse sandstone	4	
Soft, grey sandstone	9	
Coarse sandstone	11	6
Dark shale	4	6
Grey shale	26	6
Coal	1	
Fine, grey sandstone	11	
Coarse sandstone	5	6
Sandstone	6	
Mynheer seam *Coal*	6	6
Mynheer seam Shale	1	
Mynheer seam *Coal*	6	6
Grey sandstone	9	6
Brown shale	9	
Sandstone	1	8
Dark shale	5	
Clay shale	6	6
Hard shale	5	6
Soft sandstone	16	6
Clay shale	1	6
Sandstone	3	
Shale	3	
Soft sandstone	20	
Hard sandstone	3	
Clay shale	4	
Shale	13	
Black shale	0	6
Clay shale	12	6

Two coal seams are being worked on this property. These are shown in the section given above. The upper seam is locally known as the Silkstone or 12-foot seam, while the lower is known as the Mynheer or 14-foot seam. Both seams are worked by slopes driven down on the dip of the beds. The slope on the upper seam was driven over 1,200 feet from the outcrop when a disturbed and faulted zone was struck. At the time of the writer's visit to this mine, however, the workings in the lower part of this seam were on fire so that only about 600 feet down the slope could be examined. This seam averages about 12 feet in thickness, but the upper 4 feet has to be left for a roof; the entire thickness of 12 feet is, however, good coal and much of the coal that is left for a roof is recovered when the pillars are being drawn. The lower seam has a total thickness of about 12 feet, but this contains several shale and clay bands so that only about $7\frac{1}{2}$ feet is being mined, $1\frac{1}{2}$ feet being left for a roof, while the lower part of the seam, also left, is commonly very dirty. The slope on this seam has been driven about 950 feet.

When visited in July, development work only was being done and about 100 tons of coal per day were being taken out.

YELLOWHEAD PASS COAL COMPANY.

The property of this company is located at Coalspur, about 20 miles northwest of Lovett and on the branch railway which runs in from Edson. The railway between Coalspur and Lovett follows the same general direction as the strike of the rocks. The coal seams at Coalspur belong to the same series as those at Lovett. It is thought that the seams exploited by the Yellowhead Company are higher in the series than those worked by the Pacific Pass Company; but the thickness of the coal seams and the nature of the associated beds varies so much from place to place within comparatively short distances, that the relative position of the coal seams at the two mines could not be determined. The coal seams at the Yellowhead mine are on the west limb of an anticline and have a dip of 70 to 80 degrees southwest. The crest of the anticline is a little over a mile to the northeast of the mines. A section of the rocks in the vicinity of Coalspur shows a formation about 3,000 feet in thickness, composed of sandstones, shales, and coal beds, and with a conglomerate bed about 15 feet thick near the bottom of the section. The productive coal measures are in the upper part of this section and are associated with light grey sandstones and sandy shales. Although no good section of these coal measures was seen, there is a sufficient number of isolated exposures to show that this horizon contains a great deal of coal. The number of seams that are sufficiently free from rock to be workable, and also with good roof and floor conditions, are few. Two seams have been worked by the Yellowhead Pass Company. The upper seam is about 9 feet thick and the lower about 9 feet 6 inches. Slopes were sunk on both seams at an angle to the dip. The horizontal distance from the mouth of the slope to the face of the workings is about 2,200 feet. At a distance of about 1,700 feet from the mouth of the slope the two seams coalesce. The information regarding the workings was obtained mainly from the mine plans as the writer was unable to verify it by a personal inspection. The mines are closed and some of the workings are on fire.

MOUNTAIN PARK COLLIERIES.

Mountain Park collieries lie just west of the front range of the Rocky mountains at the headwaters of Macleod river. They are about 30 miles southwest of Coalspur and are connected by railway with the latter place.

This coal basin is marked by a considerable relief. The valley bottom in the vicinity of the mines is over 5,800 feet above sea-level and the higher ridges attain an altitude of 7,000 feet. This whole basin is then enclosed on the north, south, and west sides by mountain ridges which in places attain an altitude of 9,000 feet. The structure though simple in its large features is complicated in detail. The coal measures here form part of one of those large fault blocks so characteristic of the Rocky mountains. The only exception to the dominant southwestward dip are local folds in shales and drag folds on the northeast side of thrust faults. In this region, the northeastern faces of both the first and second mountain ranges are the loci of major thrust faults. The trend of the mountain ranges is very irregular and the strike of the coal measures between the mountain ranges also shows considerable irregularity. At the townsite, the strike is about 60 degrees west of north and the dip 30 degrees southwest. As we proceed northwest the whole basin is seen to pitch toward the southeast and a tight syncline causes the uppermost part of the coal measures to be repeated at the southwestern side of the basin. The western limb of this syncline is overturned and a coal

seam outcropping at the edge of the second range of mountains, and dipping southwest, has the appearance of being overlain by the thick limestone series which forms the mountains. East of the townsite, several small folds, which plunge steeply toward the east, cause the strike to change greatly within very short distances.

This basin shows a continuous section from the Palæozoic limestones and quartzites to the Upper Cretaceous. The Jurassic, represented by the Fernie formation, is composed of dark, brownish weathering shales, limestones, and black shales of marine origin. The shales of the Fernie formation holding marine

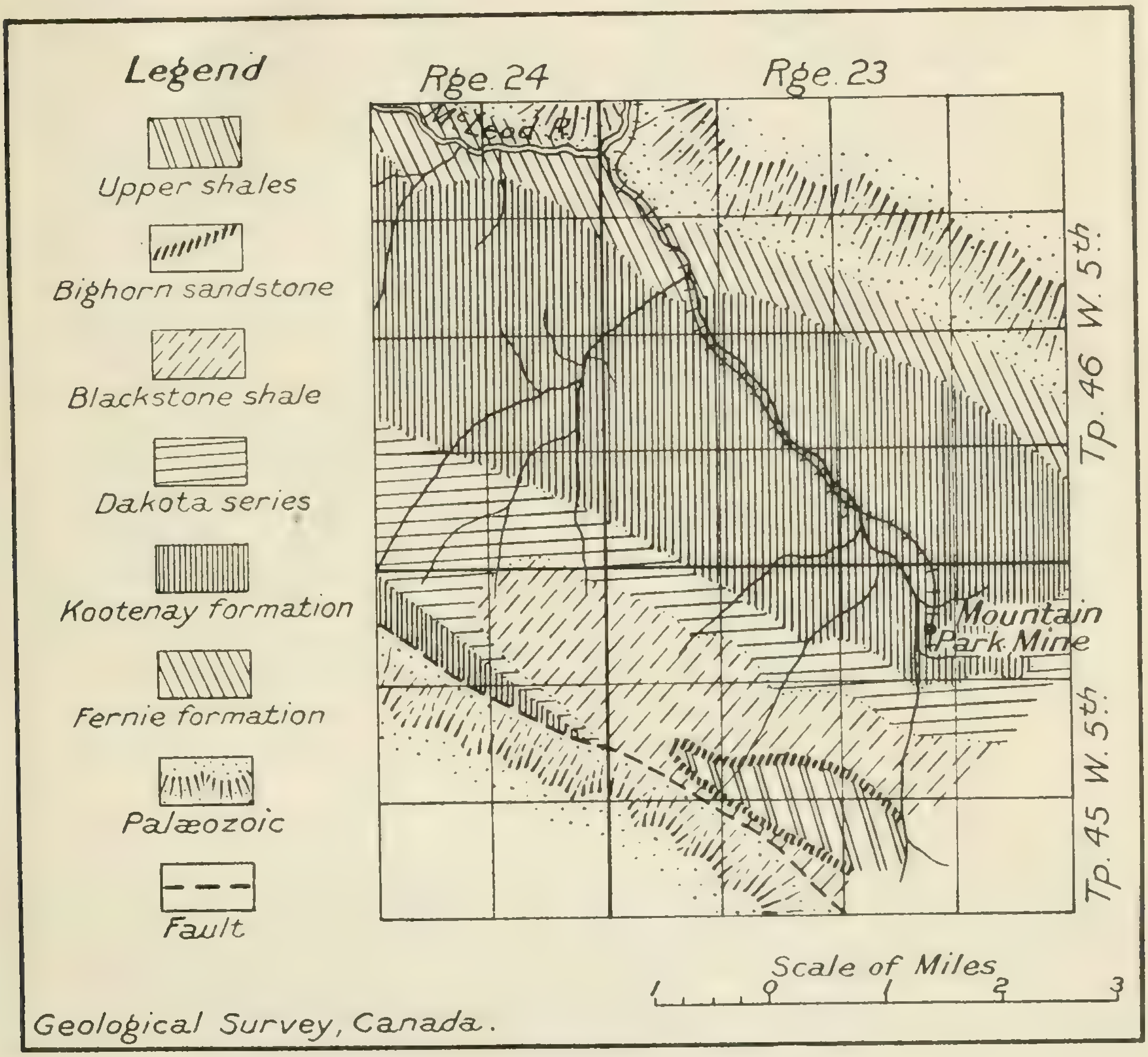


Figure 4. Mountain Park coal area.

fossils, grade upward into similar black shales with arenaceous and calcareous bands. In these upper shales no marine fossils were found and, after a stratigraphic interval of about 200 feet has been passed, the shales show numerous and well preserved ripple-marks and plant remains make their first appearance. If the uppermost bed which contains marine fossils, is the top of the Fernie formation, this formation has a thickness of about 1,000 feet, but some of the brown shales at the base may be Triassic. Overlying the Fernie is the Kootenay formation composed of shales, sandstones, conglomerates, and coal beds. The true thickness of the formation is hard to obtain on account of the disturbed condition of the rocks. Making allowance for duplication, however, the total thickness must be about 3,000 feet. The lower half consists mainly of shales;

the upper half consists of conglomerates, sandstones, shales, and coal seams. The productive coal measures are confined to the upper 1,000 feet of the formation. The contained fossils are wholly of continental origin, consisting of plant remains and a few freshwater molluscs.

Overlying the Kootenay formation is a series of grey sandstones, and thick-bedded sandy shales, with a conglomerate bed at the base. This series is about 400 feet in thickness and is generally assigned to the Dakota formation; fossils observed consisted of two or three tree trunks, 12 to 18 inches in diameter, and a few obscure impressions of leaves and rootlets.

The Dakota series grades upwards into dark grey fissile shales very similar in appearance to the Benton shales of southwestern Alberta. These shales contain marine fossils, *Inocerami* and *Prionocyclus* types being the most common. This series is about 1,150 feet in thickness and is probably to be correlated with the Blackstone shales of the Bighorn coal basin.[1] These Blackstone shales are overlain by about 75 feet of sandstone and conglomerate in which no fossils were observed. The stratigraphic horizon and the lithologic character of these rocks suggest their provisional correlation with the Bighorn formation described by Malloch.

Overlying this Bighorn series is another series of shales very similar to the shales beneath. A complete section of this upper shale formation is not present. They are poorly exposed, much disturbed, and faulted. A few marine fossils were collected from these beds but have not yet been determined.

The Kootenay formation contains many coal seams in this basin. Two of these are worked by the Mountain Park Coal Company. No. 1 seam, the uppermost, is 7 feet thick; the other seam, known as No. 3, lies about 300 feet below No. 1 and is over 20 feet thick in places, but of this only about 12 feet is mined. These seams have been opened up by slopes and tunnels on both sides of the valley. The workings on the east side have already penetrated over 3,000 feet, and on the west about 2,000 feet. The average daily output in August this year, was about 400 tons.

PEMBINA COLLIERY.

The Pembina mine is located at Evansburg about 70 miles west of Edmonton and is tapped by the main lines of both the Canadian Northern and Grand Trunk Pacific railways. The country in the vicinity of the mine is flat and for the most part covered with timber. Pembina and Lobstick rivers, which form a junction near Evansburg, flow in deep valleys, the bottom of the Pembina being over 200 feet below the general level of the country. The altitude of the strata is practically horizontal and, except for a few small local rolls, any inclination which the beds may have is to be measured in feet per mile. A correlation of the coal seams at several places indicates a gentle dip toward the west. A section of the strata in the Pembina mine shaft is about as follows:

[1] Malloch, G. S., "Bighorn coal basin, Alberta", Geol. Surv., Can., Mem. 9, pp. 35–36.

Section at Pembina Colliery.

	Strata	Thickness Feet	Thickness Inches
	Surface loam	1	
	Yellow clay	18	6
	Light grey sandstone	29	6
	Blue and grey shale	198	5
No. 1 seam	*Coal*	3	
No. 1 seam	Carbonaceous shale	3	2
No. 1 seam	*Coal*	1	2
No. 1 seam	Clay shale	0	2
No. 1 seam	*Coal*	0	8
No. 1 seam	Shale	0	2
No. 1 seam	Bony coal	2	6
No. 1 seam	*Coal*	0	10
No. 1 seam	Bony coal	0	6
No. 1 seam	*Coal*	6	0
No. 1 seam	Shale	0	2
No. 1 seam	*Coal*	3	10
No. 1 seam	Shale	0	1
No. 1 seam	*Coal*	2	4
	Sandy shale	3	2
	Sandstone	26	0
	Clay shale	3	0
No. 2 seam	*Coal*	1	6
No. 2 seam	Clay shale	0	1
No. 2 seam	*Coal*	5	11
No. 2 seam	Sandy shale	0	10

The sandstones are well exposed along Lobstick and Pembina rivers. The fossils, which include unios, stems of plants, and tree trunks, indicate an Upper Cretaceous and probable Edmonton age for this formation. As shown by the section there are two coal seams, the thick upper one is, however, too dirty and is not worked. The present owners of the Pembina colliery have concentrated their work on the lower seam. This seam is tapped by a vertical shaft about 315 feet deep and from this the workings radiate.

ISLAND LAKE COAL COMPANY.

The property of this company is located near Wabamun, about 42 miles west of Edmonton on the Grand Trunk Pacific railway. The surrounding country is fairly flat and dotted with numerous small lakes and marshy tracts. The surface is well covered with glacial debris and bedrock is rarely exposed. The mine tunnel shows the strata to be practically horizontal in attitude. The coal seam lies near the surface and has a total thickness of about 26 feet; but the upper 14 feet contains many bands of shale and is too dirty for profitable mining. The lower 12 feet is fairly clean coal and about 8 feet of this is being mined. The mine is yet in the early development stages and the main tunnel has penetrated about 600 feet from the entry.

COAL ANALYSES.

Locality.	Lab. No.	Proximate analysis, per cent. Moisture	Ash	Volatile matter	Fixed carbon	Ultimate analysis, per cent. C.	H.	S.	N.	O.	Calorific value, B.T.U.	Fuel ratio, F.C./Vol.	Carbon hydrogen ratio, C./H.	Coking properties.
Brazeau Collieries, Nordegg.														
No. 2 seam, 4,200 ft. from entry	858	0·8	14·5	15·1	69·6	76·1	3·9	0·5	1·1	3.9	13110	4.6	19·6	Poor coke.
No. 2 seam, centre of workings..	859	0·6	11·6	14·6	73·2	79·7	4·1	0·4	1·1	3·1	13690	5·0	19·7	" "
No. 3 seam, 2,000 ft. from entry	860	0·6	16·9	14·6	67·9	74·4	3·9	0·5	1·2	3·1	12790	4·65	19·1	" "
Saunders Creek Coal Co.														
Lower seam, 680 ft. from entry..	861	4·8	6·3	33·1	55·8	70·4	4·9	0·3	1·2	16·9	11930	1·70	14·6	Non.
Pacific Pass Coal Co., Lovett.														
Silkstone or upper seam, 600 ft. from entry..................	862	4·4	10·3	31·4	53·9	67·3	4·5	0·1	1·0	16·8	11410	1·70	14·9	"
Mynheer or lower seam, 900 ft. from entry..................	863	4·4	16·1	32·6	46·9	62·9	4·5	0·2	0·9	15·4	10650	1·45	14·1	"
New prospect seam, surface.....	864	8·1	7·8	38·0	46·1	59·4	4·2	0·2	0·9	27·5	9590	1·20	14·2	"
Yellowhead Pass Coal Co., Coalspar.														
Four-foot seam, near surface...	865	3·7	11·4	33·2	51·7	67·8	4·4	0·2	0·9	15·3	11400	1·55	15·4	"
Mountain Park Coal Co.														
No. 1 seam, 1,000 ft. from entry..	866	0·9	5·4	29·9	63·8	81·4	5·1	0·4	1·4	6·3	14310	2·15	16·0	Fair.
No. 2 (prospect) seam, 150 ft. from entry................	867	0·7	15·2	25·2	58·9	73·0	4·4	0·4	0·9	6·1	12760	2·35	16·7	"
No. 3 seam, 400 ft. east from slope	868	0·5	23·6	25·1	50·8	64·9	4·2	0·3	0·9	6·1	11290	2·00	15·6	"
No. 3 seam, 400 ft. lower part ..	869	0·7	22·8	23·0	53·5	66·1	4·1	0·4	1·0	5·6	11520	2·30	16·3	Poor.
No. 5 seam, 50 ft. from entry....	870	1·3	17·5	24·3	56·9	69·0	4·3	0·4	1·5	7·3	12010	2·35	15·9	"
Pembina Colliery, Evansburg.														
Lower seam, 1,000 ft. north of shaft.....................	871	5·7	11·1	32·4	50·8	61·9	4·3	0·2	1·0	21·5	10300	1·55	14·4	Non.
Island Lake Coal Co , Wabamun.														
Upper seam, 580 ft. from entry..	872	6·7	11·7	34·8	46·8	58·9	4·4	0·1	0·7	24·2	9650	1·35	13·4	"

Samples air dried as received. Samples collected by J. S. Stewart, 1916. Analyses by fuel testing division, Department of Mines.

CROWSNEST COAL FIELD, ALBERTA.

(*Bruce Rose.*)

PURPOSE AND SCOPE OF WORK.

Three months of the 1916 field season were spent in mapping the coal-bearing rocks and associated formations on the eastern slope of the Rocky mountains in southern Alberta, with the object of making a general investigation of the coal resources and of the stratigraphy and structure of the various formations. This work is a continuation of that begun by the writer in 1915 in the Blairmore map-area. An effort was made to complete the mapping of all the coal-bearing areas east of the main range of the Rocky mountains and south of the 50th parallel of north latitude. The work was carried on in the mountains and the foothills about the heads of the numerous branches of Oldman river, chief of which are the Oldman (Northfork) the Crowsnest (Middlefork), and the Castle (Southfork). It was carried east as far as the coal areas of the Kootenay formation occur and was connected with the work done by J. S. Stewart in the foothills during 1914 and 1915.[1] This along with Mr. Stewart's work completes the mapping of the Cretaceous coal areas on the east slope of the Rocky mountains south of the 50th parallel of north latitude and west of the 114th parallel of west longitude; and it is hoped to extend the investigation to include the coal areas on the west slope of the Rocky mountains in British Columbia and so complete the mapping of the rectangular area bounded by the 49th and 50th parallels of north latitude and the 114th and 115th parallels of west longitude.

The term "Crowsnest Coal Field" as applied to Alberta has reference to the coal areas on the east slope of the Rocky mountains, which are tributary to the Crowsnest branch of the Canadian Pacific railway. In this report it refers to the area south of the 50th parallel of north latitude where coal of the Kootenay formation is found and does not include the areas in the foothills and on the Great Plains where coal of the Belly River formation is mined, although much of this area is also tributary to the Crowsnest branch of the Canadian Pacific railway.

FIELD WORK AND ACKNOWLEDGMENTS.

The topographical map of the Crowsnest Forest Reserve, published by the Department of the Interior, includes the greater part of the area mapped and was used as a base for the geological mapping. This map on a scale of 2 miles to 1 inch and with a contour interval of 100 feet proved very suitable for field purposes. The system of surveying used was that of running traverses across the ridges and along stream courses. Locations of contacts, fault lines, etc., on the ridges were made by triangulation and aneroid barometer readings, and along streams by locations from prominent bends or permanently marked survey lines. Where necessary, traverses were run along formation contacts and fault lines. From the data thus obtained the geological map was compiled.

For the work in the foothills east of the area covered by the Crowsnest Forest Reserve map, the sectional sheets of the Dominion Land Surveys Branch, Department of the Interior, scale 3 miles to 1 inch, were used as a base for the mapping.

The work at the first of the season was somewhat hampered by the death of the first assistant C. B. Hamil. Mr. Hamil had spent three seasons with the Geological Survey, as field assistant, and was pursuing a graduate course at

[1] Geol. Surv., Can., Sum. Rept., 1914 and 1915.

Princeton university. He was an enthusiastic student and his death has removed a most promising geologist.

I wish to thank my assistants P. G. Dobson and A. Laferrière for their careful work and cheerful co-operation throughout the season. Thanks are also due to residents of the district for courtesies which helped to advance the progress of the work.

GENERAL GEOLOGY.

Stratigraphy. An apparently conformable series of rocks from the Devono-Carboniferous to the Allison formation (Upper Cretaceous) occurs in this area. An older series of Cambrian and Pre-Cambrian age occurs at the heads of Castle and Carbon rivers (Southfork area) overthrust upon the Cretaceous rocks, but was not investigated. Superficial deposits of glacial and river drift fill the valley and mantle the lower slopes of the mountains and hills.

Table of Formations.

Pleistocene and Recent	Superficial deposits
Upper Cretaceous	Allison formation Benton formation Crowsnest volcanics Blairmore formation
Lower Cretaceous	Kootenay formation
Jurassic	Fernie formation
Devono-Carboniferous	
Pre-Cambrian and Cambrian	

DESCRIPTION OF FORMATIONS.

Pre-Cambrian and Cambrian. A great series of sedimentary rocks containing at least one prominent lava flow, comparable to the Purcell Pre-Cambrian sills, is overthrust upon the Cretaceous rocks in the Southfork area, at the heads of the numerous branches of Castle river. They form the high mountains at the north end of Clarke range which extends southward across the International Boundary into Montana. No detailed examination of the series was made but the rocks were observed at numerous localities while mapping the fault contact between them and the Cretaceous rocks. They consist of grey, heavy-bedded, somewhat siliceous limestone, dark argillites and quartzites with some white quartzite, a dark lava flow, yellow to brown quartzite, and a red somewhat shaly argillite or flaggy quartzite. These can be correlated with the rocks at the International Boundary described by Willis as Algonkian,[1] and by Daly as Beltian, Cambrian, and Middle Cambrian.[2]

Fossils collected from beds at the top of the series are of Middle Cambrian age.[3]

Devono-Carboniferous. The Palæozoic rocks consist largely of evenly bedded, compact, grey limestone. The top beds, where observed, lie conformably under the Jurassic (Fernie formation), but the series as a whole is in most places in

[1] Willis, B., "Stratigraphy and structure, Lewis and Livingstone ranges, Montana," B.G.S.A., vol. XII, 1902, pp. 316–324.
[2] Daly, R. A., Geol. Surv., Can., Mem. 38, 1912, part I, pp. 47–95.
[3] Adams, F. D., and Dick, W. J., "Discovery of phosphate in the Rocky mountains", Commission of Conservation, Canada, p. 13.

folded and faulted relations with the Jurassic and Cretaceous. The base of the series is in no place exposed. The upper portion consists of light-coloured quartzites and siliceous limestones and may probably be correlated with the Rocky Mountain quartzite (Pennsylvanian) of the Bow River section to the north. Below the quartzitic phase there are massive, light grey, somewhat crystalline limestones, cherty limestones, a band of dark shales, and varieties of massive, concretionary, flaggy and shaly limestones. A few fossils collected from the lower beds are Devonian types and some from the upper limestones have been classed as Carboniferous, so the general name of Devono-Carboniferous is temporarily retained for the series until a subdivision is made.

These rocks are found in the main range of the Rocky mountains, where they are overthrust upon the Cretaceous rocks; in Crowsnest mountain and Goulds Dome, as overthrust outliers on the Cretaceous rocks; and in the Livingstone range and the Turtle Mountain group where they are in folded and faulted relations with the Jurassic and Cretaceous rocks.

Fernie Formation. The Fernie formation on the east slope of the Rocky mountains is principally a shale formation. It consists largely of black and grey-black, fissile, marine shales, grading to thinly bedded and shaly sandstones at the top. The weathered shales are in many places brown in colour, and clay ironstone nodules are common. A bed of green, arenaceous shale, occurring near Blairmore and on Castle river and described in an earlier report as a tuff,[1] was found under microscopic examination to consist of grains of quartz and decomposed ferromagnesian minerals and is not of volcanic origin. Limestone beds or lenses occur sparingly throughout the shales. Fossil pelecypods and belemnites indicate a Jurassic age for the formation.

At the contact with the underlying Palæozoic rocks there is a thin band of conglomerate from 1 foot to 3 feet in thickness, made up of fragments of red quartzite and bits of cherty and fossiliferous limestone set in a matrix of sand and lime. The fragments show very little weathering and are mostly somewhat angular. They probably represent surface debris which was only slightly reworked on the coming in of the Jurassic sea.

The contact with the overlying Kootenay formation is not well marked. There is a gradual change from marine shales to subaerial sandstone and the line of demarcation used is the base of the first heavy bed of sandstone. Kootenay coal occurs a short distance above this sandstone.

The maximum thickness of the Fernie formation in this area is from 700 to 800 feet. On account of its soft and fissile character it weathers readily and so is found occupying valleys and depressions.

Kootenay Formation. The Kootenay formation is the one in which all the workable coal of the district is found. It consists of alternating sandstones and shales and coal seams associated with the shales. Massive, coarse-grained and cross-bedded sandstone layers of grey colour stand out prominently. Between these are black shales, carbonaceous shales, sandy shales, and the coal seams which, on account of their softer character, have weathered more than the sandstones and are usually debris covered. The whole formation is of subaerial origin as is evinced by the character of the sediments—coarse sandstones showing cross-bedding, ripple-marks, fossil land plants, and shales associated with coal seams. The formation is of Lower Cretaceous age, as determined from the fossil plants.

The coal seams are named locally, No. 1 seam, No. 2 seam, etc. Six seams are known of which Nos. 1, 2, and 4 are mined. There are also small seams of no commercial importance. Sections measured at different points do not give

[1] Geol. Surv., Can., Sum. Rept., 1915, p. 111.

the same succession of strata. No. 1 seam at the top of the section is missing at many points. This may be due to its removal by erosion before the rocks of the overlying Blairmore formation were deposited. No. 2 seam is very persistent. A complete section measured south of Crowsnest river, at Blairmore, illustrates the nature and succession of the rocks.

Section of Kootenay Formation at Blairmore.

	Feet
Conglomerate at the base of the Blairmore formation.	
No. 1 coal seam missing but present under the conglomerate 1½ miles to the north where it has a thickness of 10 to 18 feet.	
Massive, coarse-grained, and cross-bedded, grey sandstone with prostrate fossil stems and bits of coal	39
Coal, No. 2 seam	15
Dark shale	55
Sandstone, dark grey, cross-bedded	14
Shale, black, fissile with a few sandy layers	25
Coal, No. 3 seam	2
Shale, black, sandy and carbonaceous layers with little layers of coal	81
Coal, No. 4 seam	4
Black shale	3
Coal	2
Black shale	3
Sandstone, coarse and cross-bedded	37
Shale and small coal seams	70
Massive, grey sandstone, approximately	100
Below is thin-bedded sandstone and shale assigned to the Fernie formation	
	450

Blairmore Formation. The Blairmore formation consists principally of red and green, sandy, and crumbly shales with interbedded, grey sandstones. At the base is a persistent and conspicuous conglomerate from 15 to 20 feet in thickness, made up of black, white, and red quartzite pebbles from ½ to 2 inches in diameter set in a firmly cemented, sandy matrix. The pebbles are evidently derived from the Cambrian and Pre-Cambrian quartzites found to the west. The proportion of pebbles to matrix decreases from west to east and some of the eastern exposures are merely coarse sandstone with an occasional pebble. The conglomerate has been described as marking the top of the Kootenay formation and is commonly spoken of as the Kootenay conglomerate; but it rightfully belongs to the base of the Blairmore formation. As noted above, the upper beds of the Kootenay formation, including coal seam No. 1, are missing in places, indicating an erosion interval, and the change from shale and coal to conglomerate deposition must have been connected with diastrophic changes and marks a more likely boundary for the beginning of a new formation. The conglomerate is of great importance from an economic standpoint. It is the horizon marker which is sought by all prospectors since the best prospecting ground for coal lies just below it.

Conglomerate occurs at irregular intervals throughout the formation as lenses in the sandstones. There is one fairly persistent conglomerate band about 1,000 feet above the base of the formation, which looks much like the basal conglomerate but is distinguished by a large percentage of crystalline igneous pebbles. It is well exposed on York creek one-quarter of a mile west of the International Coal and Coke Company's fan house and again on the hills between Frank and Bellevue just north of the Frank rock slide.

A limestone band associated with shale and limy sandstone was noted at several points. At Passburg it is not more than 50 feet from the basal conglome-

rate. At Frank, it is 175 feet from the base, at Blairmore, 500 feet, and north of Coleman, 550 feet.

The thickness of the formation varies from 2,000 to 3,000 feet increasing towards the west. Measured sections show a repetition of shale and sandstone from 1 to 10 feet in thickness with occasional thicker bands up to 50 feet.

Fossil plants indicate a Dakota age for the formation. McLearn collected fossils in this area in 1915 and in a preliminary statement reports that abundant angiosperms are confined to the upper 200 feet which may be of Dakota age, while the lower and greater part of the formation may be of uppermost Comanchean age.[1]

Crowsnest Volcanics. Resting conformably on the Blairmore formation and probably grading into it are beds of volcanic tuffs and agglomerates. These beds are stratified and in places contain water-worn fragments. They vary in texture from ash-fine tuffs to coarse agglomerates with fragments up to 2 and 3 feet in diameter. The colours range from light grey to green, pink, and purple. It is needless to describe all the varieties; but, conspicuous among them are: a feldspar tuff in which crystals of pink feldspar up to 2 inches in length are embedded in a fine-grained, grey matrix so that the rock has the appearance of a porphyry; an analcite porphyry occurring as fragments in the agglomerate; and varieties of tuff with many small crystals of melanite. Microscopic examination by Knight[2] has shown that the following rock types occur in the district: augite trachyte, tinguaite, andesite and analcite trachyte; and by MacKenzie[3] the following: aegirite-augite trachyte, melanite-bearing trachyte, latite, and analcite-bearing rocks for which the name blairmorite is adopted.

The greatest thickness of volcanic rock observed is in a ridge west of the town of Coleman where a section of over 1,100 feet was measured. From there the rocks thin to the north, south, and east until the Benton rests directly on the Blairmore. To the west the volcanic rocks dip under the Benton formation and do not again appear, although a small block was observed along the fault plane where the Palæozoic rocks of the main range of the Rocky mountains is thrust over the Cretaceous areas. This block is located 4 miles north of Crowsnest lake and 4 miles west of the main ridge at Coleman and has evidently been dragged in on the fault plane.

No volcanic neck or vent has been found from which the volcanic rock could have been extruded, but the centre of eruption was somewhere north and west of Coleman in the vicinity of Crowsnest mountain, for it is here that the greatest thickness of deposits is found. The occurrence at Coleman, which MacKenzie[4] states was reported to be probably a volcanic neck, was found on examination to be a piece of the volcanic rock dragged in on a fault plane; and similar occurrences were noted at intervals along this fault plane for a distance of 15 miles.

Benton Formation. The Benton is, like the Fernie, principally a marine shale formation. It overlies the Crowsnest volcanics conformably and is in turn overlain conformably by the sandstones and shales of the Allison formation. The rocks consist of brown and black, friable, and fissile shales with ironstone concretions, and a few arenaceous beds. Near the base of the formation are two sandstone layers, the upper one of which has a siliceous cement and weathers to light-whitish tints. This bed is very resistant to weathering and commonly stands in ridges, the shales on either side of it having been denuded, so that it makes a good horizon marker.

[1] McLearn, F. H., Geol. Surv., Can., Sum. Rept., 1915, p. 112.
[2] Knight, C. W., Can. Rec. Sc., Montreal, vol. 9, 1905, pp. 265–278.
[3] MacKenzie, J. D., Geol. Surv., Can., Mus. Bull. No. 4, 1914.
[4] MacKenzie, J. D., Idem., p. 13.

On account of the soft nature of the shale the rocks weather readily and complete sections are not well exposed. The rocks also show considerable minor folding in places, so that it is difficult to estimate the true thickness of the formation. It is probable that the minimum thickness for the area may be placed at 3,000 feet. The following section was measured on York creek west of Blairmore.

Section on York Creek.

	Feet
Sandstone and shale of the Allison formation	
Friable, brown-black shale with ironstone concretions and arenaceous bands	2,500
Hard, grey sandstone with siliceous cement, weathering white on the surface	60
Brown-black shale with nodules and with thin arenaceous bands	295
Grey-black, platy sandstone	25
Friable and fissile, brown-black shale	365
Crowsnest volcanics	
	3,245

At one locality a 3-foot bed of light grey clay shale is interbedded with the brown-black shale, 125 feet from the base of the formation. This occurrence is on Jackson creek, a branch of the Castle river, in sec. 23, tp. 6, range 3, W. 5th mer.—the only locality where the clay bed was seen. It was thought that it might be a fireclay but tests show that it is suitable only for ordinary brick.[1]

A considerable fossil fauna has been collected from this formation[2] and from the presence of *Baculites asper* it is referred to the Benton, or Colorado shale.

Allison Formation. The Allison formation is the youngest of the conformable series of sediments exposed in the area. It is largely a sandstone formation and was first described for this area as the Allison Creek sandstones.[3] It is the stratigraphic equivalent of the Belly River formation of the Great Plains to the east.

A thickness of from 2,500 to 3,000 feet of sediments is exposed. The top beds are in all places in faulted relations with some of the older formations but are so like the top beds of the Belly River formation, seen to the east where they are overlain conformably by the Bearpaw shales, that the above figures are thought to represent the total thickness of the formation. A close search for Bearpaw shales along the fault planes failed to reveal any.

At the base of the formation is 250 to 350 feet of massive, light grey, cross-bedded, coarse-grained sandstone which from its nature and its stratigraphic position is probably the equivalent of the Eagle formation. Above this is 50 feet of grey shale with interbedded coal seams of no economic importance. Then follows 2,000 to 2,500 feet of interbedded, grey sandstone and grey-green shale. Towards the top, the formation becomes very shaly and at several localities black shale and a small coal seam were observed just where the older formations are faulted over the Allison rocks. This coal is thought to be the equivalent of that mined at the top of the Belly River formation east of the mountains. At one locality a conglomerate layer was noted well up in the upper sandstone and shale division.

McLearn reports two brackish-water and two freshwater faunules from this formation, all of which appear to be typical of the Belly River.[4] This, along with the presence of coal and the general arenaceous character of the formation proves it to be of continental origin.

[1] Geo. Surv., Can., Mem. 47, pp. 25–28, and Mem. 65, pp. 54–59.
[2] McLearn, F. H., Geol. Surv., Can., Sum. Rept., 1914, p. 62.
[3] Leach, W. W., Geol. Surv., Can., Sum. Rept., 1911, p. 196.
[4] McLearn, F. H., Geol. Surv., Can., Sum. Rept., 1914, p. 62.

Superficial Deposits. Glacial gravels mantle the lower slopes and fill the bottoms of the main valleys. They were deposited by Pleistocene valley glaciers and on the retreat of the ice the valleys were blocked. Recent stream action has removed and terraced the gravels and has in many places cut through them to bedrock. Lateral moraines are still apparent in the Crowsnest valley west of Coleman. Talus deposits along the steep slopes and a general veneer of rock debris and humus on the gentler slopes mark the effects of recent weathering. At several places rock slides of huge proportions have occurred. The largest and best known of these is the Frank rock slide of 1903.

STRUCTURAL GEOLOGY.

The structure in the Crowsnest area of Alberta is that of the Rocky Mountain system in general—a roughly parallel succession of folds and thrust faults trending in a north-northwesterly direction. The thrust which caused the folding and faulting came from the west, for the rocks on the west sides of the fault planes have been shoved up and eastward over the rocks on the east sides and the dips on the western arms of the anticlinal folds are less steep than on the eastern arms. The structure is expressed topographically by a series of parallel ridges and mountain ranges with steep faces to the east and gentle slopes to the west. The crests of the ridges are formed of the more resistant rocks, limestones, sandstones, conglomerates, and volcanic agglomerate, while the valleys are occupied by the softer sandstones and shales.

The dominant structural features of the area are the high limestone mountains of the main range of the Rocky mountains on the west, and the Livingstone range on the east. Between these ranges is a relatively lower area of Cretaceous rocks which Dawson named "The Crowsnest Cretaceous Trough."[1] East of the Livingstone range the foothills are composed of faulted and folded Cretaceous rocks which repeat on a smaller scale the structural features of the Rocky mountains. The foothills area and the Crowsnest Cretaceous trough are very similar both structurally and topographically and are really continuous with one another. In passing south the Livingstone range gradually dies out and the Cretaceous rocks of the foothills connect with those of the Crowsnest Cretaceous trough by way of the Castle River valley.

South of Castle river the north end of the Clarke range abuts on the area of the Crowsnest Cretaceous trough and the regular structure of the ridges changes to a northwest-southeast direction. It appears that the thrust here must have come from the southwest. But after rounding the north end of the Clarke range the regular north-northwesterly trend again becomes dominant in the foothills to the south and east.

One exception to the general rule of thrust faulting from west to east occurs near the town of Hillcrest where the Hillcrest Collieries, Limited, are mining coal. A syncline of Kootenay and the overlying Blairmore rocks plunges to the south and to the north ends where the rocks come to the surface, and the outcrops of the coal measures can be traced in a semicircle connecting the east and west arms of the syncline. Here on both the east and west sides of the basin, rocks of the Blairmore formation are faulted in. It appears that the rocks were first folded and that the main thrust was exerted some distance below the present surface level so that when the break occurred the end of the synclinal basin was tilted upwards. The fault on the east side is then of the common thrust type but the one on the west side is the reverse of the common type, since there, the rocks on the east side have moved upward relatively to those on the west side. The two faults run together a short distance to the north and the rocks at the junction are very much broken up.

[1] Dawson, G. M., Ann. Rept., Geol. Surv., Can., 1885, p. 67B.

ECONOMIC GEOLOGY.

Coal mining is the principal industry of the district. The workable coal occurs only in rocks of the Kootenay formation and up to date seams Nos. 1, 2, and 4 are the only ones mined (see section of Kootenay formation page 110). The coal is bituminous and is in general a good steam and coking coal. An average analysis of the coal is, approximately, as follows:

Water	1·00 per cent
Fixed carbon	57·00
Volatile matter	26·00
Ash	16·00

There are at present six working collieries, all situated in the valley of Crowsnest river where they are served by the Crowsnest branch of the Canadian Pacific railway. There are also numerous prospects and a number of small mines which supply the local demand in outlying districts. Four collieries were closed in 1914 owing to the temporary depression following the outbreak of the European war. These are situated in the eastern part of the district where the coal is not so clean as that from farther west on the same seams and none of them had reached full development; for these reasons they have not been re-opened. In 1916 the working collieries were not able to supply the demand for coal. According to the published figures the yearly output for the Crowsnest district in Alberta reached its highest figure in 1913 when 1,849,435 tons were produced.[1]

As noted above all the working collieries are situated in the Crowsnest valley, Middlefork area. When the economic conditions warrant the opening of more mines the valleys of the Oldman and Castle rivers offer easy entrance to the Northfork and Southfork areas respectively. The structural conditions in the Northfork area are similar to those in the Middlefork area. A number of the seams are continuous from one to the other and the prospects show them to be approximately equal in thickness and quality. In the Southfork area the structure is complicated by the overthrust of the Clarke range. The coal outcrops are not so regular and in many of the prospects examined the coal is so broken that it cannot be worked in competition with the more regular seams of the Middlefork and Northfork areas.

OIL AND GAS, ALBERTA.

(*S. E. Slipper.*)

OIL.

In 1916 there were twenty standard drilling outfits working in the foothills in the search for oil. A brief summary of the work done in the different fields is here given to supplement previous reports by the writer.

SHEEP RIVER AREA.

In this field the drilling is passing from "wild cat" stage into that of legitimate prospecting or even actual development.

Record Well. In sec. 4, tp. 19, range 2, W. 5th mer., the Record Oil Company continued work on the test-hole begun in 1914. The present depth is about 2,900 feet. Most of this year's (1916) work consisted in clearing out some 700 feet of cavings which had collected during the preceding winter when the well was shut down.

[1] Ann. Rept. Dept. Public Works, Alberta, 1913, p. 65.

This drill-hole penetrated the Dakota at 2,320 feet where it tapped a flow of about 50,000 cubic feet of gas per day.

No petroleum has been found other than a small showing of oil at 700 feet in the Benton formation. However, the hole has not penetrated deep enough to tap the three lower horizons in which oil is known to occur at other points along the anticline.

Alberta Pacific Oil Company, Acme Well. In December 1916, this well had reached a depth of 2,200 feet and at this horizon a fair showing of dark green oil occurred. At about 1,780 feet a previous showing was encountered and this is the depth at which the Dakota formation was penetrated. These are known as the No. 2 and No. 1 oil horizons respectively.

Mount Stephen Oil Company, Well No. 2. This company began drilling on the NW. ¼ sec. 7, tp. 20, range 2, W. 5th mer., a few hundred feet southeast of the Southern Alberta Well No. 1. A depth of 1,600 feet has been attained. The drill is still working in Benton formation.

Southern Alberta Oil Company, Well No. 1. This well, which is the most promising in Alberta at the present time, has given the field the status of a commercially productive area. (This well is located in sec. 18, tp. 20, range 2, W. 5th mer. ?).

Late in 1915 a small still and condenser system was erected on this location and since then gasoline, kerosene, and a light lubricating product have beeu produced to the limit of the plant's capacity. The company's storage capacity is not very large and hence the maximum production that might be obtained from well No. 1 has never been ascertained.

The following facts regarding this well are given by E. G. Voss:

Analysis of Oil from Well No. 1, Southern Alberta Oil Company.

Temperature intervals, degrees Centigrade	Vol. of distillates per cent	Main products
38–75 75–100 100–125 125–150	5·8 16·0 20·0 16·2	Gasoline fraction 58% Gravity 0·7280 = 62°Be.
150–175 175–200 200–225 225–250 250–275 275–300	9·2 5·8 4·8 4·0 2·5 2·1	Kerosene fraction 28·4% Gravity 0·7968 = 45·7°Be.
300–325 325–350	2·0 1·0	Light lubricating 3% Gravity 0·8390 = 37°Be.
350 and up	9·0	Paraffin residue
	1·6	Loss
	100·00	

"The oil is a thin mobile liquid with strong penetrating odour. Its colour is greenish brown by reflected light and bright brown by transmitted light. It is a paraffin base.

Sp. gr. at 15·5° C. is 0·7605 or 54° Beaume.

"Both gasoline and kerosene fractions distill over water-white. The lubricating fraction is a pale yellow and the paraffin residuum is a dark green vaseline-like solid."

The oil was encountered in the well at a depth of 3,500 feet and is from the 2,718-foot oil horizon of the Calgary Petroleum Products well No. 1, that is from oil sand No. 3.

It filled the 3,500-foot hole to the top of the casing (6 inches diameter) in seventeen hours. The writer does not know of any tests as to the rate at which the oil can be lowered in the hole. There is no appreciable quantity of gas with the oil.

The well is connected by a 2-inch pipe-line to a storage tank. When more crude oil is required a valve at the casing head is open and the oil flows under considerable pressure into the tank. The flow is not continuous, but data on the actual amount that can be obtained in this manner is not available; it probably is between 35 and 50 barrels per day.

The company is making preparations to install a complete refinery.

Gasoline manufactured by the company is selling on the Alberta markets and maintains a selling price of 3 cents per gallon below the price of imported gasoline. The product has a very objectionable odour owing to the fact that it is really nothing but an unrefined distillate. When the agitators now being installed are completed this odour will be eliminated from the oil.

Southern Alberta Oil Company, Well No. 2. This well, located about 800 feet north of well No. 1 and about 200 to 400 feet farther east from the apex, is about 3,150 feet deep. The indications are very promising. The president of the company stated that oil was found at 1,855 feet, 2,720 feet, 2,970 feet, and 3,100 feet, and that a total production of 20 to 30 barrels a day from these sands was estimated. The hole has not penetrated to the main oil horizon which was found at 3,500 feet in No. 1.

Alberta Southern Oil Company. This well is in the NE. ¼ sec. 13, tp. 20, range 3, W. 5th mer. The hole has reached a depth of 2,800 feet. There was a small showing of oil at 1,800 to 1,900 feet and a small gas flow at 2,800 feet. Drilling has stopped temporarily.

Illinois-Alberta Oil Company. This company has taken over the old Northwest Pacific Company's well No. 2, which had been drilled some 300 feet. The new owners are making preparations to continue the drilling.

Prudential Oil Company. A small quantity of oil was found at the 2,250-foot horizon in this well. A charge of nitroglycerine was exploded at the oil sand with the hope of increasing the flow, but there were no appreciable results. The present production is about five to six barrels per day.

Calgary Petroleum Products Company, Well No. 1. Some extended tests have been carried out at this well to ascertain if the extraction of the liquid hydrocarbons from the gas is commercially practicable. The gas which escapes from the well contains the lighter petroleum fractions as a vapour, evident to the eye. Oil will also rapidly collect on the hand if held in the escaping gas. Attempts have been made to condense the gasoline content of the gas by an experimental compressor plant, but, for reasons not fully reported, evidently without success.

Experiments involving the principle of absorption of the contained liquids by passing the gas through liquid absorbers (petroleum distillates of known gravity) are said to give more satisfactory results than the compressor plant tests. Mr. A. W. Dingman, the company's field superintendent, has arranged an ingenious system of expansion and contraction chambers and traps through which the gas is passed immediately after leaving the casing head. From this apparatus 20 to 30 gallons of 65 degree Baume gasoline of pure water-white colour are collected per day.

Oil still flows from this well at indefinite intervals particularly after the gas has been under pressure for any length of time. On December 12, 1916, the

writer witnessed a 100 barrel flow of 45 to 50 degree Baume light green transparent oil.

The Calgary Petroleum Products Company have erected a small two unit still and condensing plant near the wells.

CARDSTON DISTRICT.

J. S. Stewart who mapped the geology of this area describes the rocks at the surface as of Belly River formation. This series of beds continues down from the surface to 1,150 feet and is then succeeded by 785 feet of black shales, to 1,935 feet; these have all the appearances of typical Benton strata and are classified as such. The sandstone beds from 1,935 to 2,090 feet are of a different formation from the Benton. They were at first classified as Dakota but it has since been decided that they are Belly River beds brought to this lower position by an overthrust.

Such a correlation has been made on the strength of the following: Stewart estimated that the Benton formation is at least 1,100 feet thick, while the well record gives only 785 feet of Benton. The sandstone samples obtained from 1,935 to 2,090 feet are not at all similar to typical Dakota sandstones but are much like Belly River rocks. On the surface, a few hundred feet east of the well a very definite fault is visible with the fault plane inclined westward.

Drilling was carried on in the Cardston district by a syndicate known as the L.H.D. Company and by the Macfarlane Oil Company of Oklahoma and Kansas.

Macfarlane Oil Company. This company began drilling in February 1916 on the NE. ¼ sec. 14, tp. 2, range 26, W. 4th mer., some 6 miles southwest of the town of Cardston. The drill had reached a depth of 2,090 feet when the hole was abandoned. No gas, oil, or water-bearing beds were encountered, nor were there any favourable indications of oil.

The following is a condensed log of the well:

Log of the Macfarlane Oil Company's Well.

	Feet
Light grey clays and silt sandstones	0– 100
Light grey sandstones with shale partings	100– 215
Blue shale	215– 420
Light grey sandstone	420– 775
Light grey sandstones, light green strata, bluish shale	775– 945
Fine light grey sandstone	945–1,150
Blue black shale	1,150–1,440
Light green shale and silt	1,440–1,510
Blue black shale	1,510–1,935
Grey sandstones and light green shales	1,935–2,090

L. H. D. Company. The company has three rigs in operation, located on a narrow anticlinal fold which is well exposed in section on St. Mary river near well No. 2 in sec. 9, tp. 1, range 25, W. 5th mer. The beds exposed on the crest are of the Belly River formation. The fold has a northwest trend and well No. 1 in sec. 36, tp. 1, range 26, W. 4th mer., is on the west limb.

The equipment of well No. 1 was destroyed this past summer (1916) by fire. No. 2 and No. 3 were abandoned soon after the Macfarlane company stopped work. No. 2 reached a depth of 1,600 feet and stopped in Benton strata: No. 3 was working in Belly River beds at 800 feet when drilling was discontinued

Livingstone Fork Syndicate, Well No. 3. This well, located on sec. 21, tp. 19, range 2, W. 5th mer., has reached a depth of 2,700 feet. Drill samples show Benton formation at this depth. Drilling is in progress.

Alberta Associated Oil Company, Well No. 2. This well, located on sec. 7, tp. 16, range 2, W. 5th mer., was temporarily abandoned in 1915, but during the past season the hole was cleaned out and drilled deeper. A small seepage of dark green oil was found at 2,300 feet. Drilling was continued to a depth of 2,605 feet when work ceased for the winter. The hole was still in Benton formation at 2,605 feet.

Viking Well. This well is one of seven owned by the Northern Gas and Development Company and situated 6 miles due north of the village of Viking. In well No. 2 a quantity of heavy black oil was obtained in or near the lower gas sand. An analysis of this oil furnished by the company follows:

Analysis of Oil from Viking Well.

Temperature intervals, degrees Centigrade	Vol. per cent distillates	Main products
50 –75	none	
75 –100	3	Gasoline fraction
100–125	1	5%
125–150	1	
150–175	2	
175–200	2	
200–225	3	Kerosene fraction
225–250	4	22%
250–275	5	
275–300	6	
300–325	4	Lubricating fraction
325–350	11	15%
Above 350	58	Residue

Sp. gr. at 60° F.— 0·935 = 19·7° Be.
Character of oil—thick, black, viscous liquid.
Character of liquid—flows slightly at 70° F.
Analyst—Milton Hersey Company, Limited.

PEACE RIVER LANDING.

Peace River Oil Company Limited. In the Peace River district the Peace River Oil Company, Limited, are drilling below Peace River Landing and reported finding oil at two horizons. As they may not yet have reached the tar sands there seems to be some probability of success. The log of the well is submitted:

Extracts from Log of Well near Peace River Landing.

	Feet
River gravel and stones	32
River gravel and stones	32– 64
Fine sand	64– 91
Sand and blue clay at 93	91– 103
Blue clay and lime rock at 126	103– 136
Lime rock	136– 163
Blue sandy shale	163– 179
Blue sandy shale with thin bands of sand rock about every 8 to 10 feet; at 220 feet struck small flow of gas and salt water	179– 277
Blue shale	277– 344
Grey sand rock	344– 367
Blue shale	367– 415
Grey shale rock; struck good flow of gas, making flame about 4 feet high; gas has distinct odour of petroleum	415– 431

	Feet
Blue shale	431– 495
Sand rock, another flow of gas with strong petroleum odour	495– 520
Blue shale	520– 545
Slate	545– 555
Blue shale	555– 607
Sand rock	607– 621
Brown shale	621– 647
Grey lime rock	647– 691
Blue shale	691– 723
Band of grey lime rock	723– 734
Blue shale; at 850 feet very strong smell of heavy asphalt oil	734– 857
Grey lime rock; good showing of heavy asphalt oil	857– 870
Sand rock becoming very hard at 880 feet; oil would probably give 5 barrels per day if pump put in	870– 883
Grey lime rock still very hard; oil showing not any stronger as oil sand has been passed through; small flow of gas at 910 to 915 feet	883– 927
Blue shale	927– 980
Sand rock with good showing of oil of better quality than last	980
Sand rock; more oil being encountered	980– 992
Sand rock	992–1,045
Blue shale	1,045–1,057
Sand rock cemented with lime, small amount of oil showing in this formation	1,057–1,083
Brown shale saturated with oil	1,083–1,085
Grey lime rock	1,085–1,093
Grey lime rock and very light blue shale	1,093–1,100
Blue shale	1,100–1,107

GAS.

Eight standard rigs were working during the summer in Alberta in the search for gas. The following notes record the operations at the several locations.

Provincial Government Well at Ponoka.

The Provincial Government recently drilled a gas well on the grounds of the asylum at Ponoka. The well is now 2,350 feet deep and has 8-inch casing down to 2,139 feet. Gas was encountered at the following depths, given in feet: 853, 912, 1,106, 1,396, 1,524, 1,872, 1,930, 2,257, and 2,300.

Down to 1,935 feet the flows of gas are small and of no commercial importance. At 2,257 feet there was for a time an open flow of 100,000 cubic feet per day with rock pressure of 410 lbs., but this was reported as fast failing. According to the Geological Survey's small scale map of Alberta the rocks at the surface of Ponoka are of the Paskapoo formation. A log of the well compiled by the Department of Public Works at Edmonton follows:

Log of Provincial Government Well at Ponoka.

	Feet
Sand (water at 75 and 125 feet)	0– 137
Blue clay	137– 158
Shale	158– 178
Coal, 12 inches	178– 179
Shale	179– 195
Blue clay	195– 209
Shale	209– 300
Coal, 25 inches thick	300– 302
Blue clay	302– 309
Brown shale	309– 340
Shale, lime	340– 349
Black shale	349– 390
White sand (gas at 409)	390– 421
Black shale (5 inches coal at 433)	421– 450
Brown shale	450– 460

	Feet
Coal, 8 feet thick	460– 468
Brown shale	468– 525
Lime (not hard)	525– 545
Hard sand (water at 548)	545– 560
Soft sand	560– 565
Blue clay	565– 600
Lime	600– 617
Black shale	617– 642
Grey sand	642– 651
Black and brown shale	651– 715
Hard lime	715– 727
White sand	727– 750
Black and brown shales	750– 850
White sand (gas at 853)	850– 855
Brown shale	855– 867
Grey lime	867– 878
Pink rock	878– 900
Grey sand (gas at 912)	900– 915
Black shale	915–1,038
Blue mud	1,038–1,058
Brown shale with sandstone partings; gas at 1,106	1,058–1,138
Sand	1,138–1,148
Black and brown shales	1,148–1,260
Sand	1,260–1,270
Brown and black shale	1,270–1,380
Sand	1,380–1,400
Black and brown shale	1,400–1,462
White sand	1,462–1,471
Blue black and brown shale	1,471–1,654
White sand	1,654–1,800
Black shale	1,800–1,810
White sand	1,810–1,862
Brown shale	1,862–1,880
Black shale	1,880–1,930
Grey, brown, and black shale	1,930–2,070
White sand	2,070–2,086
Black shale	2,086–2,090
Alternating beds of black and brown shales and white sands	2,090–2,257
Main flow of gas at	2,257

The log is inserted here as an interesting record of the strata of the Upper Cretaceous of Alberta. Although the rock descriptions are rather vague so that it is not easy to divide the log into formations, it seems probable that the coal horizon at 460 feet is in the Edmonton.

Viking Gas Field.

The Northern Gas and Development Company of Edmonton are developing a block of leases 6 miles due north of the village of Viking for the purpose of obtaining gas sufficient to supply the city of Edmonton with fuel and power. Up to the present four wells (Nos. 1, 2, 3, and 4) have been completed, while Nos. 5, 6, and 7 are being drilled. The development in this field has not proceeded far enough to allow of any detailed information being published.

The capacity of the completed wells varies from 1,700,000 cubic feet to 5,000,000 cubic feet per day open flow. The rock pressure is about 700 pounds. There are two gas horizons; at 2,150± and 2,350± feet. The upper sand gives off the larger volumes.

Drilling begins in horizontal Belly River beds. An 8-foot coal seam is passed through at 700± feet and there is a strong flow of brackish water at 740± feet. A shale formation, evidently, is encountered at 800 to 850 feet and the gas sands are probably in the lower part of this formation.

Drilling near Irma.

In 1914 and 1915 the Gratton Creek Oil Company drilled a hole on sec. 7, tp. 45, range 8, W. 4th. mer., to a depth of 1,620 feet. Owing to drilling troubles the hole was abandoned at this depth. The log of this well was supplied to the writer by Mr. Charles Taylor of Edmonton.

Log of Well near Irma.

	Feet
Drift	0– 25
Soft grey sandy clay	25– 107
Blue sandstone and fossils	107– 109
Grey shale bands of blue sandstone—shells	109– 134
Dark shales; coal seams	134– 140
Bluish grey shales	140– 175
Dark shales, coal	175– 177
Blue sandstone shells	177– 192
Brown clay	192– 200
Light grey sandstone, carbonaceous	200– 210
Light grey sandstone with clay	210– 215
Dark grey shale	215– 230
Grey shale	230– 300
Grey sand	300– 342
Grey shale a 2-foot hard shell	342– 377
Grey shale	377– 520
Hard shell	520– 522
Grey shale	522– 552
Hard shell	552– 554
Grey shale with hard shells at 645, 750, 850, 960; oil at 1,215	554–1,345
Lime shell	1,345–1,353
Grey shell	1,353–1,405
Hard shell	1,405–1,410
Grey shale, oil at 1,582	1,410–1,582
Grey shale	1,582–1,620
Bottom at	1,620

Gas at 192 feet.
Water at 270 feet.
Water and oil at 300 feet.
Oil at 1,215 and 1,582 feet.
Gas 500,000 cubic feet per day, 500 lbs. pressure at 1,620 feet.
Belly River formation to 342 feet.
Benton formation 342 feet to bottom.

The Western Petroleum Company have begun drilling on sec. 4, tp. 45, range 8, W. 4th. mer.

The Alberta Pacific Oil Company are rigging up on sec. 6, tp. 45, range 8, W. 4th mer.

The Alberta Associated Oil Company are hauling in equipment preparatory to drilling north of the village of Irma.

Drilling at Vegreville.

The first attempt at finding gas in the anticline crossing the Battle river was made at Vegreville station on the Canadian Northern railway in 1912 and 1913. A small showing of gas was obtained, but when the well reached a depth of 2,000 feet the attempt was abandoned and the casing pulled. The well was finished April 6, 1913. As the department was not supplied with samples from the well no advice as to the horizon reached could be given. J. S. Stewart of this department obtained permission to examine the samples that were preserved and the following log has been condensed from his notes.

Log of Well at Vegreville.

	Depth in feet
No record	0– 20
Clay shale—slate grey, very fine-grained, small quartz grains, few specks carbonaceous matter	20– 25
Sand, fine-grained, light yellow, iron stained, quartz, carbonaceous matter	25– 30
Mud and sand, some coarse sand, brownish grey, calcareous	30– 35
Sand and mud, quartz grains as large as ¼ inch in diameter, dark grey	35– 50
Sand, light grey, contains small grains of resin ⅛ inch in diameter, fine-grained	50– 55
Clay, grey, calcareous, small flakes of mica, carbonaceous matter	55– 80
Sand, light grey, very calcareous, contains pebbles as large as ⅜ inch	80– 130
Clay or shale, grey, slightly calcareous, fine-grained, contains small specks of resin	130– 155
Shale, grey, contains small grains of coal, a thin coal bed here, very calcareous, slightly sandy	155– 165
Sandstone, very calcareous, quite porous, coarse-grained	165– 175
Shale, grey, gives a slight action with acid, contains a little lime, darker at bottom and contains a thin bed of coal	175– 185
Sandstone, light grey, contains a little lime, slightly calcareous, medium-grained	185– 190
Shale, light chocolate brown and grey, slightly carbonaceous	190– 200
Coal, dirty, bed at least 6 feet	200– 205
Shale, brownish grey, concretionary, slightly calcareous	205– 240
Sandstone and shale, sandstone very light grey, slight action with acid, shale, dark grey	240– 255
Shale, dark grey, slightly sandy, contains specks of coal	255– 315
Shale, light grey, slight action with acid, contains some concretionary material and some carbonaceous shale	315– 325
Shale and sand, gas at 328 (2 to 5 feet sand), shale, light grey, contains some carbonaceous shale	325– 340
Shale, dark grey, carbonaceous, contains some specks of coal	340– 355
Shale, dark grey, strong action with acid, contains a little carbonaceous shale	355– 365
Shale, light grey, slight action with acid, sandy, contains a thin sandstone, a little coal at 360 feet	365– 385
Sandstone, light grey, contains a little carbonaceous matter, strong acid reaction	385– 390
Shale, chocolate brown, contains a little sandstone and carbonaceous shale, slight action with acid	390– 510
Shale, grey, and sandstone, fair action with acid	510– 515
Shale, light brown, and sandstone comparatively coarse, strong action with acid, gas reported	515– 520
Shale, bluish grey, slight action with acid, contains a little carbonaceous shale	520– 560
Shale, pronounced brown, strong action with acid	560– 565
Shale, blue grey, slight action with acid, very fine-grained	565– 570
Shale, brown, sandy, fair action with acid	570– 575
Shale, blue grey, strong action with acid	575– 585
Shale, brown, fair action with acid	585– 615
Shale, light blue grey, slight action with acid; traces of coal at 860, 885, 975, 1,020, and 1,030 feet	615–1,030
Shale, blue grey, slight action with acid, contains fragments of coal at 1,050, 1,085, 1,100, 1,120, 1,200, and 1,225 feet	1,030–1,225
Shale, dark blue, very carbonaceous, strong action with acid	1,225–1,250
Shale, light blue, slight or no action with acid	1,250–1,285
Shales, light blue, sandy, and some carbonaceous matter, contains shells and specks of coal at 1,315 feet	1,285–1,320
Shale, light blue, contains a little white sandy shale and carbonaceous shale	1,320–1,355
Blue shale, slightly sandy, gas about 225,000 feet, reported at 1,360 feet	1,355–1,365
Blue shale, slightly sandy, a few fragments of coal at 1,375, 1,385, and 1,390 feet, shells and carbonaceous shale at 1,475 feet	1,365–1,475
Strata below this probably Benton in age.	
Shale, dark grey to black fissile	1,475–1,565
Shale, dark grey to black, a little gas reported here	1,565–1,570
Shale, calcareous, strong acid reaction, dark grey in colour to black	1,570–1,700
Shale, dark grey to black, fair action with acid, not as fissile as above	1,700–1,745
Shale, dark grey to black, no acid reaction	1,745–1,860
Shale, light brown, sandy, slight acid reaction	1,860–1,865
Sandstone, brown, very fine-grained, strong acid reaction, a small flow of gas from 2-foot bed of sand. Bottom of sand reported at 1,872 feet	1,865–1,875
Shale, dark grey to black, fissile, iron-stained, no action in acid	1,875–2,000

Altitude of surface 2,082 feet above sea-level. The major part of the gas came from 1,360-foot sand—very little gas from the 1,870-foot sand. Total flow reported to be about 225,000 feet.

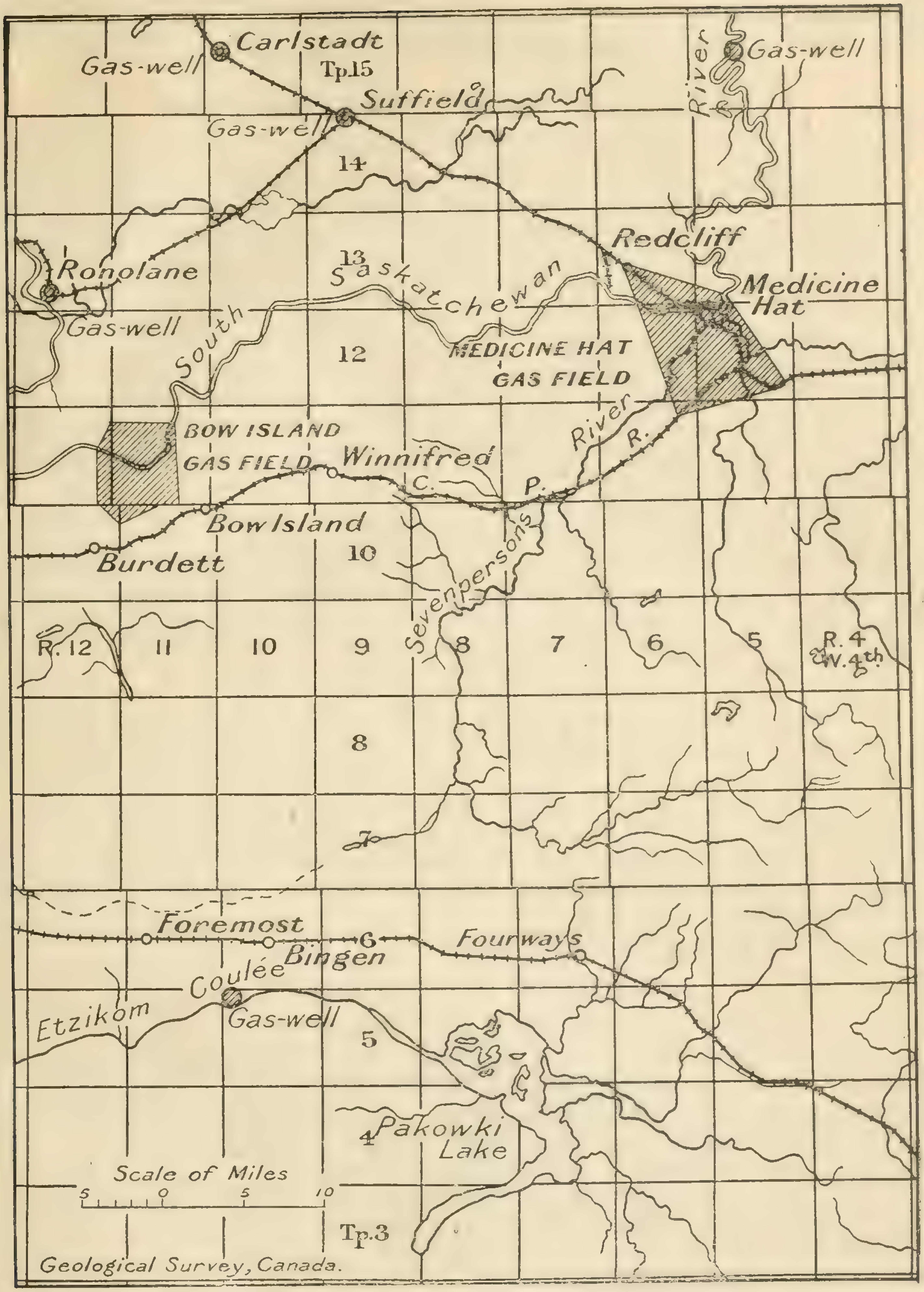


Figure 5. Gas fields of southern Alberta.

Southern Alberta.

The Canadian Western Natural Gas, Light, Heat, and Power Company are drilling two wells for gas, north of the village of Burdett.

The United Oil Company completed well No. 3 in sec. 31, tp. 5, range 10, W. 4th mer. A fuller report on the Southern Alberta gas fields, dealing particularly with the Medecine Hat and Bow Island fields, follows.

Medicine Hat and Bow Island Gas Fields.

INTRODUCTION.

Several gas-producing areas have been developed in Alberta, the most important fields being the Bow Island, Medicine Hat, and Viking. Other smaller, isolated producing areas are the Black Diamond Oil field; the Foothills west of Olds (Monarch and Mount Stephens wells), Wetaskiwin, Tofield, etc.; Brooks; Bassano; Alderson (Carlstadt); Cassils; Langevin; Foremost (United No. 3 well); Milk River (Beaver well); and the northern Athabaska fields (Pelican, Victoria, and other wells).

The Bow Island and Medicine Hat areas (Figure 5) have been developed until they have attained an advanced stage in commercial production. The cities of Calgary, Lethbridge, Macleod, Medicine Hat, and Redcliff, and some smaller towns as well as several large industrial plants, utilize the gas from these fields for light, heat, and power.

For much of the information upon which this summary report is based, the writer is indebted to Mr. R. S. Winter, superintendent of the Medicine Hat Gas department; the superintendent and drillers of the Canadian Western Natural Gas, Light, Heat, and Power Campany; the officials of the Gas Company at Redcliff; Mr. W. Currie, driller; Mr. A. G. Devenish, president, United Oil Company; Mr. Wm. Jewell, geologist, and others.

GEOLOGY.

Only the economic aspects of the fields will be dealt with in this report. For information on the geology, the reader is referred to other reports[1] of the Survey.

Briefly, the strata are of Cretaceous age. The Medicine Hat gas occurs in the Milk River sandstones (Eagle formation) or equivalent horizon, and the Bow Island gas in a sandstone of the lower Benton formation. The structure is a broad, low anticline plunging slightly northward. The Bow Island area is near the top of this fold, while the Medicine Hat area is on the east limb; but locally the beds are practically horizontal.

MEDICINE HAT GAS FIELD.

Development of Shallow Gas.

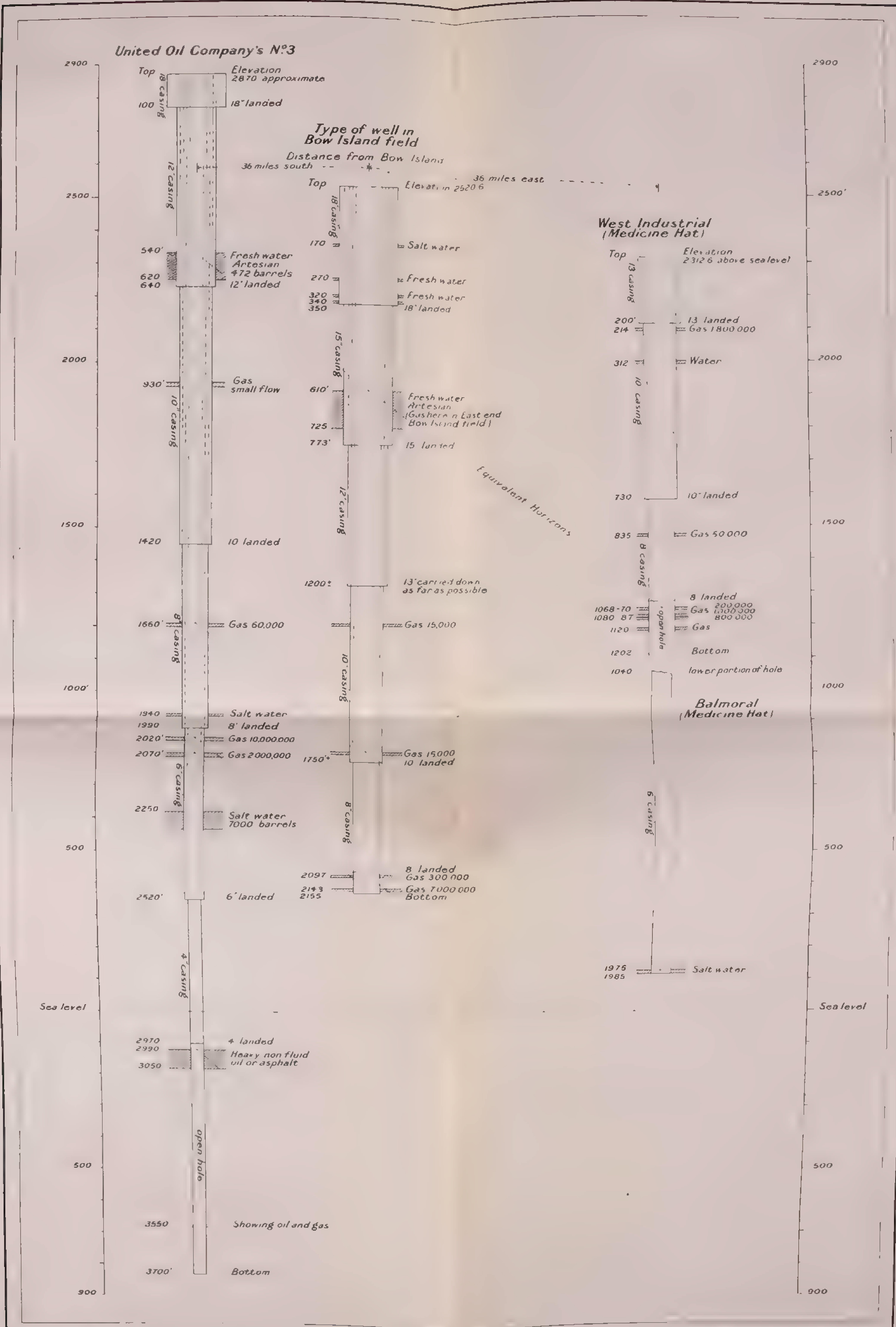
Small seepages of gas occur in the bed of the Saskatchewan river; they are made evident by a continuous stream of bubbles rising to the surface of the water. These seepages have been noticed at several places along the river near Medicine Hat and farther downstream, at the Rapid narrows. Many shallow water wells in the district give off small volumes of gas.

The first wells were drilled in Medicine Hat by a development company in 1901. These wells penetrated only to the shallow gas horizon.

The following is a list of the shallow wells:[2]

Four city wells 700 feet deep.
Central Canada Packing Company, 750 feet, 2-inch casing, wet well, not in use (1910).
C. Colter, Second avenue, 700 feet, 3-inch casing, 270 pounds pressure when capped.
H. Yuill, South railway station, 850 feet, 4⅝-inch casing, 270 pounds pressure when capped.

[1] Dowling, D. B., "Water supply, southeastern Alberta", Geol. Surv., Can., Sum. Rept., 1915, p. 102.
Dawson, G. M., "Geology of the Bow and Belly River districts", Geol. Surv., Can., Rept. Prog. 1882-83-84.
McConnell, R. G., "Geology of the Cypress Hills and Wood Mountain areas," Geol. Surv., Can., Ann. Rept., vol. I, pt. C.
Dowling, D. B., "Southern plains of Alberta", Geol. Surv., Can., Mem. 93 (in press).
[2] Ries, H., Geol. Surv., Can., Sum. Rept., 1910, p. 179.



Geological Survey, Canada

Diagram showing water, gas and oil horizons in drilled wells of Southern Alberta.

To accompany Summary Report by S.E. Slipper 1916

Development of Deep Gas.

In 1908 the Canadian Pacific railway drilled to 1,000 feet and reached the deep gas or the main Medicine Hat gas horizon. Since then all wells have been drilled to the deeper horizon and the shallow wells in use have been gradually abandoned. In 1910 there were six deep wells, five of which were owned by the city. At the present time there are thirty-two wells deriving gas from the Med-

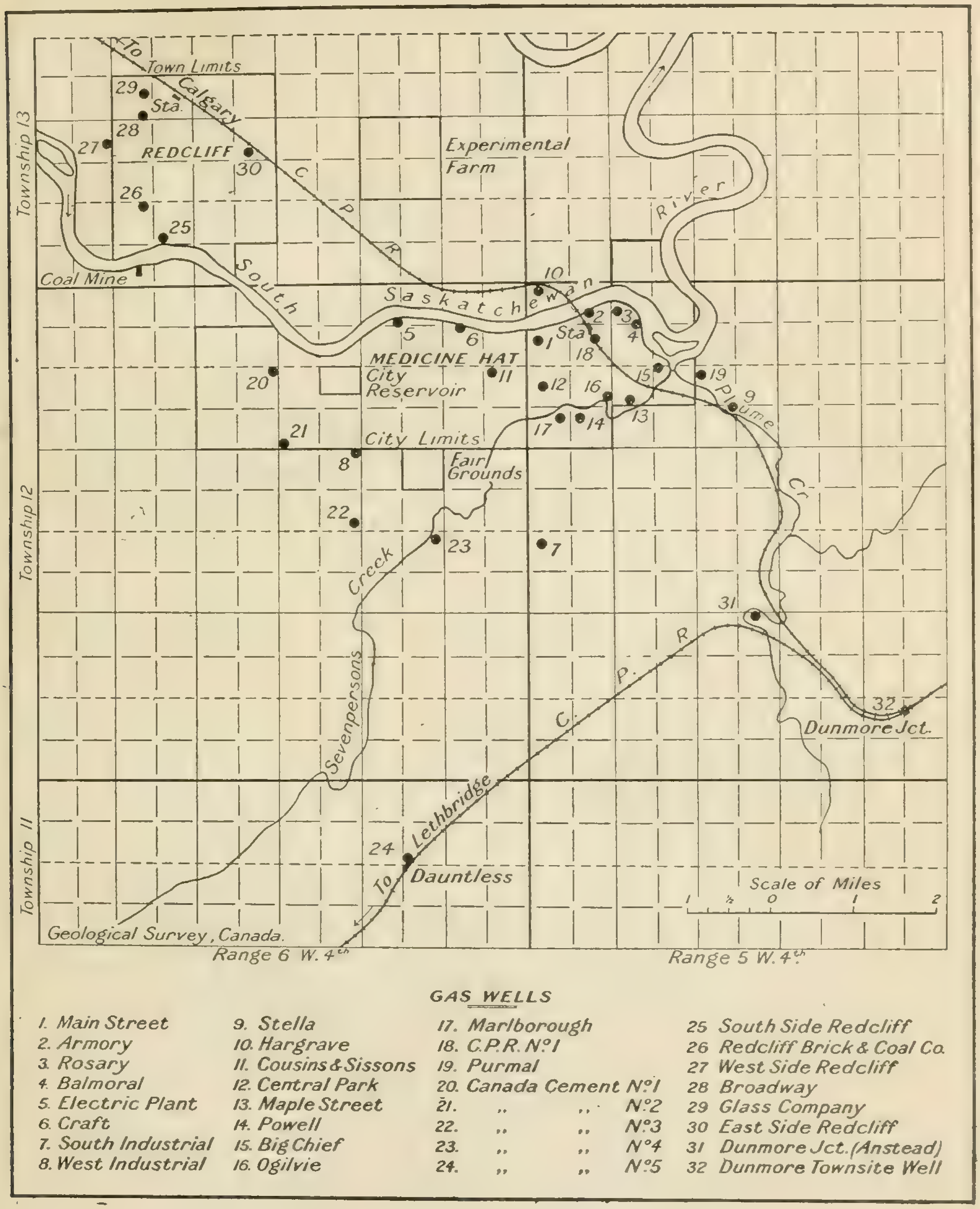


Figure 6. Locations of wells in Medicine Hat gas field.

icine Hat horizon: fourteen of these are owned and used by the city of Medicine Hat; three are owned by the city but are used solely by private concerns; ten are owned by private corporations; four are owned by Redcliff, and one by the town of Dunmore (Figure 6).

The following is a tabulated list of data relating to the wells of this field:

Gas Wells of Medicine Hat and Vicinity.

Ref. No. Fig. 6	Name of well	Location	Depth, feet	Elevation, feet above sea-level	Size, inner casing, inches.	Volume, cu. ft. per day open flow.	Owner.	Used.	Remarks.
1	Main street	SW.¼ 31–12–5	1,000	2,202·95	4⅝	2,225,000	Medicine Hat	City	
2	Armory	NE.¼ 31–12–5	1,200	2,145·05	6	3,000,000	"	"	
3	Rosary	NW.¼ 32–12–5	1,000	2,132·65	4¼	2,000,000	"	"	
4	Balmoral	SW.¼ 32–12–6	1,000	2,128·95	6	2,500,000	"	"	Drilled to 1,985
5	Electric plant	NW.¼ 35–12–6	1,134	2,167·75	8	4,000,000	"	"	feet and then
6	Craft	SW.¼ 36–12–6	998	2,148·05	8	3,300,000	"	"	filled up to
7	S. Industrial	NW.¼ 18–12–5	1,200	2,346·95	6	2,300,000	"	"	1,000.
8	W. Industrial	NW.¼ 22–12–6	1,202	2,312·82	8	2,100,000	"	"	
9	Stella	SW.¼ 28–12–5	1,002	2,147·65	8	2,200,000	"	"	
10	Hargrave	NW.¼ 31–12–5	1,042	2,165·65	6	2,500,000	"	"	
11	Cousins and Sissons	NE.¼ 25–12–6	1,075	2,269·44	6	2,800,000	"	"	
12	Central park	NW.¼ 30–12–5	1,120	2,262·87	8	3,000,000	"	"	
13	Maple street	NW.¼ 29–12–5	980	2,131·35	6	2,500,000	"	"	
14	Powell	SE.¼ 30–12–5	1,100	2,139·55	6	2,900,000	"	"	
15	Big Chief	12–5	1,100	2,133·55	6	2,800,000	"	Alberta Prod. Co.	
16	Ogilvie	NE.¼ 30–12–5	1,039	....	6	3,000,000	"	Ogilvie Mills	
17	Marlborough	SW.¼ 30–12–5	1,000	2,151·65	6	1,800,000	"	Maple Leaf Mills	
18	C.P.R. No. 1	SE.¼ 31–12–5	900	....	6	1,000,000	C. P. R.	C. P. R.	C.P.R. 1 and 2 are
	C.P.R. No. 2	SE.¼ 31–12–5	1,015	....	8	2,500,000	"	"	about 100 ft. apart
19	Purmal	NW.¼ 28–12–5	..	....	–	2,000,000	Purmal Co.	Purmal Co.	
20	No. 1	NE.¼ 28–12–6	..	....	–	2,080,000	Can. Cement Co.	Can. Cement Co.	Average capacity is given.
21	No. 2	SE.¼ 28–12–6	..	....	–	2,080,000	"	"	
22	No. 3	SE.¼ 22–12–6	..	....	–	2,080,000	"	"	
23	No. 4	NE.¼ 14–12–6	..	....	–	2,080,000	"	"	
24	No. 5	Dauntless Sta.	..	....	–	2,080,000	"	"	
25	Southside	NE.¼ 5–13–6	..	....	–	4,000,000	Redcliff Gas Co.	Town	Stated that capa-
26	Brick Co's.	NW.¼ 5–13–6	..	....	–	4,000,000	" Brick&Coal Co.	Owners	city of Redcliff
27	Westside	NE.¼ 7–13–6	..	....	–	4,000,000	" Gas Co.	Town	wells averages be-
28	Broadway	SW.¼ 17–13–6	..	....	–	4,000,000	" " "	"	tween 4,000,000
29	Glass Co.	SW.¼ 17–13–6	1,220	....	6	4,000,000	Munderloh Glass		and 5,000,000 cu.
30	Eastside	NE.¼ 9–13–6	..	....			Co.	Owner	ft. The Broadway
31	Anstead (Dunmore Junc.)	NE.¼ 9–12–5	..	....	–	4,000,000	Redcliff Gas Co.	Town	is strongest, while
32	Dunmore..............	Townsite	..	....	–	3,000,000	C. P. R.	C. P. R.	the Southside well
					–	?	Dunmore town	Owners	is the weakest. Said to be a wet well. Stated to have a low capacity.

Redcliff Wells. The information regarding the Redcliff wells was obtained from the officials of the Redcliff Light and Power Company. It is approximate and possibly the volumes stated are somewhat above the actual open flow of the wells. The figures given are the average open flow. The Southside well is the weakest, while the Broadway well is said to give the greatest open flow measurement.

Information on the Dunmore well was not available at the time of the writing. It was stated that the well is of low capacity.

With the exception of the Canada Cement Company's well at Dauntless, all the holes are located within tps. 12 and 13 in ranges 5 and 6, W. 4th mer. Most of the wells in the city of Medicine Hat are located in the valley of Saskatchewan river and at elevations approximately, of 2,120 to 2,170 feet. Those located on the prairie are at elevations of 2,250 to 2,350 feet. The wells at Redcliff and Dunmore are at least as high as the South Industrial well (No. 7) i.e., 2,350 feet above sea-level.

The depths of the holes depend upon the elevations. The wells are drilled to different depths below the gas, some 100 feet deeper.

The sizes of the inner casing (liner pipe) used in the wells are $4\frac{5}{8}$, 6, and 8 inches. The holes recently drilled are either 6 or 8 inches diameter.

The maximum capacity recorded is 4,000,000 cubic feet open flow per day (excepting the Redcliff measurements). Wells giving from 3,000,000 to 2,500,000 cubic feet are considered good, while those with less than 2,000,000 cubic feet are classified as poor wells.

Wells deriving gas from the Medicine Hat gas horizon have an estimated total open flow per twenty-four hours as follows:

Medicine Hat city wells	37,425,000	cubic feet.
Privately owned wells	23,500,000	" "
Wells at Redcliff (estimated)	24,000,000	" "
Wells at Dunmore (estimated)	3,000,000	" "
Total	87,925,000	

Assuming that under working conditions a well can deliver 60 per cent of the open flow measurement, the total working capacity of the field at the present time is 52,755,000 cubic feet per twenty-four hours.

The rock pressure or maximum pressure when the well is closed averages 556 pounds. The working pressure or pressure gauged at the casing head varies between 225 and 375 pounds. The gas is delivered to domestic consumers at 8 ounces pressure and to industries at pressures up to 50 pounds.

No estimate could be formed of the consumption of gas, since no trustworthy records are kept. The consumption of gas is many times greater in the winter than in summer because the gas is used throughout the area for heating. The amount of gas used is much less than the amount available; for instance, the village of Redcliff uses only a small fraction of the 24,000,000 cubic feet which is claimed as the well capacity. The wells of the Canada Cement Company are closed except No. 2 which at present is blowing wide open, and the well at Dunmore is used only to a very limited extent. In Medicine Hat large quantities of gas are used by some of the consumers. The following estimates will give an idea of the amount taken by the larger concerns:

City water works	23,000,000	cubic feet per month.
Ogilvie flour mill	23,000,000	" " " "
Alberta Clay Products Company	30,000,000	" " " "
Rolling mills	15,000,000	" " " "
Lighting system (gas)	3,000,000	" " " "
Canadian Pacific railway	30,000,000	" " " "
Several others	15,000,000	" " " "

Many industrial plants use the gas of this field, including: sewer-pipe, brick, tile, and pottery plants; iron foundry and rolling mills; brass foundry; nut and bolt factory; cement works; planing mills; several flour mills and elevators; electric lighting plants, waterworks plant, large greenhouses, and other works.

The gas is sold to domestic consumers at 10 to 15 cents per 1,000 feet and to industrial concerns at ½ to 5 cents per 1,000 feet.

Well Drilling.

Standard rigs are used to put down the holes. The rock is fairly uniform and easily drilled, consisting mostly of soft sandy shale with occasional sandstone "shells." The walls of the holes stand up fairly well and if the water is cased off no serious caving can take place to cause delays. The time taken to drill a well varies from six weeks to three months. The average cost of a well connected up for delivery of gas is $8,000.

In the West Industrial well a 13-inch casing was carried to 200 feet to shut off surface water. Below that a 10-inch casing was put down to 740 feet to shut off the water at 315 feet and an 8-inch casing to about 10 feet above the deep gas. The remainder of the hole is left uncased.

In the Balmoral Street well, which was drilled to 1,984 feet, an 18-inch drive pipe was inserted to 58 feet to hold back the surface water, followed by 352 feet of 13-inch casing to shut off the water sand at 210 feet, by 10-inch to just above the deep gas horizon, by 8-inch to 1,500 feet, and by 6-inch to the bottom of the hole.

The general practice is to allow for at least three strings of casing:

(1) Drive pipe to hold back surface water from 50 to 200 feet.
(2) Casing to hold back water at 200 to 350 feet and to control the shallow gas at 600 to 800 feet.
(3) Liner pipe landed above the deep gas.

All the casing is left in the hole permanently. Because of the soft nature of the rocks the gas cannot be controlled by one string of pipe, as is shown by the present condition of the Canada Cement well No. 2. On the completion of the well one of the drillers attempted to remove some of the pipe to repair a leak which had developed with the result that the gas got beyond control, broke through the upper strata, and formed several other vents, some of them at a distance of 40 feet from the original hole. The trouble was aggravated by the subsequent removal of all the casing, which allowed the upper part of the well to cave in. The Cement Company has gone to a great expense in an endeavour to re-drill the hole and replace the casing so that the gas can be controlled, but they have not yet been successful.

Gas Horizons.

To simplify description the position of the gas horizons will be referred to their elevation above sea-level.

Deep Gas. The top of the "main" or "deep" gas horizon is about 1,250 feet above sea-level (a variation of from 1,245 to 1,265 feet was noted in the logs). The gas occurs in three or four "streaks" or seams in a thickness of 60 to 80 feet. The middle gas is generally the strongest and the lower one the weakest.

The "sand" of the deep gas horizon is a dark, fine-grained, sandy shale having a low porosity. It is generally quite dry and being firm, it stands up well so that it is very seldom necessary to clean out the wells by allowing them to blow.

Shallow Gas. There is another gas at 1,480∓ feet above sea-level, called the "shallow gas", which was the first used at Medicine Hat. It occurs in a sandy shell in the soft shales, has a pressure of 100 to 300 pounds, and gives off volumes up to 60,000 cubic feet per twenty-four hours.

The shallow sand is usually wet and continually gave trouble by caving and clogging the hole. This is one of the reasons why it is not drawn from at the present time.

Other Gas Sands. Occasionally a small gas flow occurs at 2,070∓ feet elevation.

Horizons Lower than the Deep Gas. In 1911, the city of Medicine Hat began the Balmoral Street well by which it was intended to explore the strata below the gas horizon. The hole penetrated 1,080 feet deeper than the gas and at that depth (1,975–1,985 feet) tapped a strong flow of salt water. This salt water sand is about 140 feet above sea-level. The work was immediately stopped and the hole was plugged up to the 1,000-foot level.

In the Bow Island and United No. 3 wells a small gas flow occurs at the same horizon as the salt water in the Balmoral well and it would appear that the Bow Island gas horizon is about 350 feet below this water sand. The deep drilling in the Balmoral well did not reach the Bow Island gas horizon so that the presence of gas or water in it can only be proved by deeper drilling.

Extent of the Field.

How far the gas field extends beyond the present proved area has not been determined. We know that artesian water fills the sand at Bow Island and southward. Some of the easterly wells at Bow Island give off gas as well as water. Probably the district underlain by high pressure gas should not be expected farther west than halfway between Medicine Hat and Bow Island. Seepages of gas are known as far north as the Rapid narrows on South Saskatchewan river. There is no doubt that these come from the shallow gas and do not necessarily prove the existence of the deep gas to that distance north.

A well was drilled at Suffield in 1915 in which fresh water was found at 660 feet and a flow of 350,000 cubic feet of gas at 885 to 960 feet.

There is a well at Alderson (Carlstadt) which at 913 feet gives a gauge pressure of 350 pounds of gas. These occurrences may be equivalent to either the shallow or the deep gas. The most southerly well drilled in the field, the Canada Cement well at Dauntless, is a very poor one giving not more than 1,500,000 cubic feet per twenty-four hours.

Source of the Gas.

The source of the gas is unknown. It is possible that it has collected as a seepage from the Bow Island gas horizon. The several small gas seams occurring at various depths from the surface down to the Bow Island gas lends support to this theory.

Life of the Field.

There does not seem to be any appreciable decrease in the volume of the gas. It was stated to the writer that recently one of the wells was allowed to flow wide open for a considerable time and then a gauge was put on. The pressure increased to the same amount as the original capped pressure of the well but at a considerably slower rate.

Conservation of the Gas.

No great waste of gas has been permitted in the western gas fields. Strenuous efforts are being made to close in the Canada Cement Company's well No. 2 which has got out of control.

Tests should be made on the wells occasionally so that any decline in volume may be detected.

An exploratory well drilled through the deeper horizons to the Bow Island sand would prove the presence or absence of gas in it and would determine the extent to which it is advisable to draw on the present supply. Such a trial well might be driven with advantage to themselves by the cities and industries in the vicinity.

Gas Wells for Irrigation Pumping.

The bench lands which extend along South Saskatchewan River bottom from Medicine Hat to Rapid narrows make admirable alfalfa-growing land when irrigated. The only available source of water for irrigation is the river which lies about 40 feet below the bench lands and this means that the water must be pumped some 50 feet.

At Drowning Ford ranch in the NE. $\frac{1}{4}$ of sec. 21, tp. 15, range 5, W. 4th mer., a well has been drilled to the shallow gas sand. The following is a log of this well:

4-inch casing to	88 feet.
Water and light flow of gas	140 to 142 feet.
$3\frac{1}{2}$-inch casing to	176 feet.
Gas at 175 lbs. pressure	662 to 668 feet.
Bottom of hole at	668 feet.
2-inch liner pipe is used.	

Mr. J. H. Spencer, owner of the ranch, estimated that there is an open flow of 50,000 cubic feet per 24 hours. The well has not been tested on the pumping project. The ranchers in the area who have made a study of the conditions, state that the well would be required to deliver enough gas to run a 50-horsepower gas engine. The amount of gas required for 1-horsepower per hour is about 14 to 16 cubic feet. This would require a production of from 20,000 to 25,000 cubic feet per 24 hours. Owing to the soft nature of the shallow gas sand it soon becomes plugged by caving, so that it is doubtful if a well giving an open flow measurement of 50,000 cubic feet could be expected to deliver more than 20,000 cubic feet for any length of time. According to the rough calculations made here, this would be sufficient gas to run the 50-horsepower pumping plant, but the question should be referred to a gas-engine expert before deciding definitely.

There is little doubt that the shallow gas would be available on all these bench lands as far north as Rapid narrows at an approximate depth of 650∓ feet. However, it is not necessarily true that the deeper gas would be found in all these localities as it is probable that the deep gas sand plays out to the north. The presence of the deep gas can be ascertained only by drilling.

BOW ISLAND GAS FIELD.

General Description of Wells.

The wells of this area (Figure 7) are located along South Saskatchewan river north of the villages of Bow Island and Burdett, in the east half of tps.

10 and 11, range 12, and in tp. 11, range 11, W. 4th mer. The first well (No. 1 Canadian West Natural Gas, Light, Heat, and Power Company) was drilled by the Canadian Pacific Railway Company. The Canadian Western Natural Gas, Light, Heat, and Power Company acquired this well in 1911 and since then have completed sixteen others, while at the time of writing two more are nearing completion. There are, in addition to those owned by this company, two other wells in the field; one owned by the village of Bow Island and another belonging to the Southern Alberta Land Company.

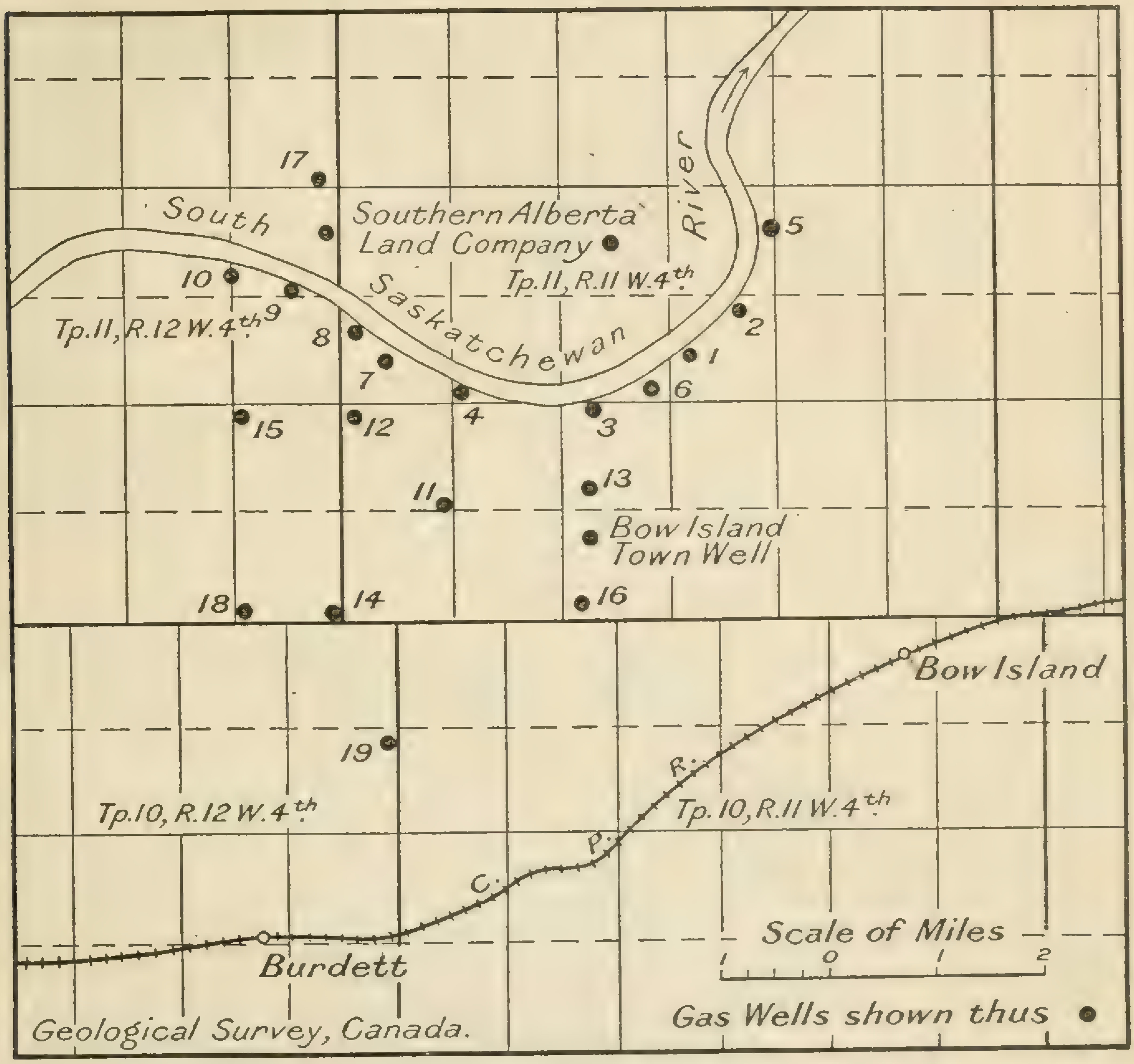


Figure 7. Locations of wells in Bow Island gas field.

Ten of the wells are located close to the river near the bottom of the coulée and have a general elevation of 2,275 feet above sea-level. The remainder are situated on the prairie with elevations of 2,460 to 2,490 feet above sea-level.

Below is a list of the wells with locations and open flow measurements of the gas:

Wells of Bow Island Field.

No.	Location					Open flow, cu. ft. in 24 hours.
	Legal subdivision	Sec.	Tp.	Range	West of mer.	
1	5	15	11	11	4	10,000,000
2	15	15	11	11	4	7,000,000
3	16	9	11	11	4	15,000,000
4	4	17	11	11	4	29,000,000
5	9	22	11	11	4	1,250,000
6	1	16	11	11	4	4,200,000
7	6	18	11	11	4	7,000,000
8	12	18	11	11	4	12,500,000
9	2	24	11	12	4	7,000,000[1]
10	Road SE.¼	23	11	12	4	7,000,000[2]
11	1	7	11	11	4	6,000,000
12	13	7	11	11	4	22,000,000
13	SW. ¼	9	11	11	4	7,000,000
14	1	1	11	12	4	7,000,000
15	13	12	11	12	4	4,000,000
16	4	4	11	11	4	3,857,000
17	1	25	11	12	4	2,400,000
18	4	1	11	12	4	Being drilled.
19	16	25	10	12	4	" "
	Bow Island Town well	4	11	11	4	12,000,000
	South Alberta Land Co.	24	11	12	4	12,000,000

[1] Estimated flow.
[2] Estimated flow.

The wells on the prairie have depths of 2,100 to 2,255 feet and those in the coulée of 1,890 to 1,930 feet. The diameters of the inner casing are either 6-inch or 8-inch, all the wells on the prairie being 6-inch except Nos. 18 and 19, now being drilled.

Wells Nos. 4, 12, and 3 have the remarkable open flows of 29,000,000, 22,000,000 and 15,000,000 cubic feet respectively, per 24 hours. The average well measures from 7,000,000 to 12,000,000 cubic feet. No. 5 and No. 17 are quite low, 1,250,000 and 2,400,000 cubic feet, respectively. The total open flow of the wells per 24 hours is 181,207,000 cubic feet.

The rock pressures gauge from 700 to 800 pounds.

The Canadian Western Natural Gas, Light, Heat, and Power Company pipe the gas to Calgary, Lethbridge, Macleod, Manton, and smaller towns along the Calgary-Lethbridge branch of the Canadian Pacific railway. The following facts on the consumption of gas by the city of Calgary were given by Mr. H. B. Pearson, general superintendent of the gas company, in a newspaper interview:

"The capacity of the Bow Island-Calgary pipe-line is 39,000,000 cubic feet per day. The average amount of gas used by Calgary is 10,000,000 cubic feet per day. The maximum amount ever supplied Calgary in 24 hours was 37,000,000 cubic feet during the cold weather of January, 1915. The lowest amount used was 4,000,000 cubic feet in 24 hours."

Well Drilling.

Standard cable tools and heavy duty, standard, 84-foot derricks are used to drill wells in the Bow Island field. The average time to drill a well is about four months. They cost in the neighbourhood of $20,000.

The well is generally begun with 18-inch casing which is carried down to 200 to 350 feet to shut off surface water and four or five shallow water sands. The 15-inch casing is landed at a depth sufficient to seal the very heavy flow of fresh water which begins to come in the hole at from 550 to 650 feet. This water sand is about 100 feet thick. It is often very difficult to shut off this water.

Below the water sand the rocks are very soft and when being drilled form a thick sticky mud in which the tools cannot be operated effectively. In addition, these soft shales are continually caving. Hence three and often four changes of pipe are made below the 15-inch, i.e., down to 13-inch, 10-inch, and 8-inch, or 13-inch, 10-inch, 8-inch, and 6-inch, in order to get the drill down to the gas. Each string is drilled, driven, or under-seamed down as far as possible before a change is made. The last 100 feet above the gas usually gives more trouble than any other part of the well by caving and heaving and the sticking of the tools. Below the gas horizon, in the United No. 3 well, the soft caving shales continued down to the salt water sand (a distance of 150 feet). Below the water the rocks are fairly hard and comparatively easy to drill.

Gas Horizons.

Bow Island Gas Horizon. The gas occurs in two and in places in three seams in a horizon of sandstone beds, the top of the upper sand being from 382 to 440 feet above sea-level. The thickness of the horizon averages 35 feet. There is a slope northward of the gas sand from No. 14 to No. 17 of nearly 15 feet to the mile. There is a dip east from No. 11 of about 7 feet to the mile and also a dip west from No. 11 which seems to be more abrupt than the dip eastward. The lower sand is the more important, the one or two seams above this usually give only small volumes of gas.

The sandstone in which the gas occurs is medium-grained and light grey in colour; the grains are mostly white or transparent quartz and somewhat angular. There is practically no cement and the grains can be easily abraded from the rock by rubbing with the finger. It is very porous and pitted. The rock breaks into thin plates parallel to the bedding and the joint planes are covered with a thin black "scum" or film.

The sandstone is as a rule free from water but when it is found depressed below the normal elevation, salt water has come into the drill hole.

Other Horizons. At an elevation of about 750 feet above sea-level, a small gas flow is often met with; also another one at 1,200 feet$\mp$ elevation. These are of no importance. Gas sometimes occurs in small quantities in the artesian water sand.

Horizon Below the Gas. The beds below the gas horizon have not been explored in the Bow Island field, proper, but the United Oil Company's well No. 3 in sec. 31, tp. 5, range 10, W. 4th mer., south of Foremost, was drilled 1,680 feet below the Bow Island gas horizon. In this well a great flow of salt water was encountered 180 feet below the gas; the estimated flow was 7,000 barrels per day. At 920 feet below the gas a 60-foot bed of sandstone saturated with asphalt was penetrated. This material would not flow but came up as large lumps adhering to the tools. At 1,480 feet below the gas a show of gas and oil occurred.

Extent of the Field.

The log of the United No. 3 proves that the Bow Island gas horizon extends at least 36 miles south of Bow Island. At this well the estimated open flow was 13,000,000 cubic feet per day.

The limits of the field east or west have not been ascertained.

North of the field at Ronolane in sec. 8, tp. 13, range 12, W. 4th mer., a well was drilled with the following result:

Fresh water	775 feet.
Gas, flow of 26,000 cubic feet per 24 hrs	2,032 "
Salt water	2,044 "
Salt water (bottom of hole)	2,080 "

It is fairly certain that the horizons at 2,030, 2,044, and 2,080 feet are equivalent to the Bow Island gas horizon and are here mainly occupied by salt water. So there is a possibility that the gas is not present very far north of the area already proved.

Well No. 17, the most northerly of the Gas Company's wells, produced a quantity of salt water from the gas sand and a poor flow of gas.

Source of the Gas.

The great thickness of heavy oil sand at 920 feet below the gas suggests a possible source for the gas.

SALT AND GYPSUM DEPOSITS OF THE REGION BETWEEN PEACE AND SLAVE RIVERS, NORTHERN ALBERTA.

(*Charles Camsell.*)

INTRODUCTION.

The field season of 1916 was occupied in an examination of the gypsum beds exposed on the lower part of Peace river, on Slave river, and on Salt river, with a view to determining their economic importance and to ascertain whether or not they have associated with them other valuable salts, especially salts of potash.

Sections were examined on Peace river at Little rapids and Peace point, on Slave river at La Butte and point Ennuyeux, and on Salt river at the brine springs directly west of Fort Smith. In the course of this work some data were collected with regard to the range, numbers, and general condition of the wood bison, and a memorandum embodying these data has been submitted to the Commissioner of Dominion Parks and the Commission of Conservation. A short visit was also paid in August to Mr. A. E. Cameron on Great Slave lake whose work was under my general supervision.

In addition to the regular field work about six weeks in the spring and autumn were spent in the examination of tungsten and molybdenite deposits for the Canadian Munitions Resources Commission in the provinces of Quebec, New Brunswick, and Nova Scotia.

For assistance in forwarding the work of the party in northern Alberta, my acknowledgments are due to Mr. Card of Fort Smith, Inspector Tupper, Royal North West Mounted Police of Fitzgerald, and Mr. Brabant and other officials of the Hudson's Bay Company in the Edmonton and Mackenzie River districts.

GENERAL CHARACTER OF THE DISTRICT.

Topography.

The area in which the deposits of gypsum and salt occur, is situated in the angle between Peace and Slave rivers east of longitude 113 degrees and north-

ward to latitude 60 degrees. It forms a small part of the great plains of western Canada and has the physiographic characteristics of the plains farther south. East of the area, is the rocky Laurentian Plateau region whose western border follows more or less closely the valley of Slave river. On the west is a high plateau, known locally as Caribou mountain, which rises 2,000 feet or more above the level of the plain.

The area is comparatively level, having an altitude of about 800 feet above the sea and sloping very gradually towards the east and north. On the south its surface is only about 60 or 80 feet above the level of Peace river, and on the north it drops away sharply in an escarpment 150 to 200 feet high overlooking Salt river and Salt plain. The only irregularities of the surface are due to ridges of sand, boulders, or limestone, which are rarely as much as 100 feet high. Frequently its surface is broken and pitted by numerous sink holes due to the solution of beds of gypsum which underlie a great part of the region.

There are few lakes in the region and many of them contain water too brackish to drink. Streams also are few in number and very small in size, and it appears as if a great part of the drainage is subterranean through the gypsum strata.

The whole area is more or less timbered, though interspersed at intervals with irregular patches of open prairie a few hundred yards in length and breadth. The largest area of such open country is situated on either side of Salt river about the forks of the stream and is known as Salt plain. Salt plain covers an area of perhaps 150 square miles and is by no means an unbroken stretch of treeless prairie, but is interrupted by strips of timber consisting of poplar, willows, and spruce. All the prairie openings are grass-covered with the exception of some barren clay flats or playas, aggregating some square miles in extent, in the immediate vicinity of the brine springs. The timber is mainly poplar (*Populus tremuloides*), individual trees of which often attain a diameter of 2 feet. On the sandy or bouldery ridges are jack-pines and in the lower, wetter tracks are belts of good spruce with some tamarack and balsam poplar.

WOOD BUFFALO.

The boundaries of this region coincide more or less closely with the limits of the range of the southern herd of wood buffalo. These animals are estimated to number in all about 600 and are about equally divided into two main herds, one occupying the region under discussion and the other an area farther north lying between Buffalo and Little Buffalo rivers. A belt of muskeg country separates the northern from the southern herd and prevents migration from one to the other. Each of the main herds is broken up in smaller bands of 10 or 12 individuals and except in the mating season in July and early part of August they are never found together in large numbers. To prevent their extermination, the buffalo have been protected for over twenty years and no hunting of them has been allowed during that time. There is no doubt that there has been an increase in their numbers as a result of the protection afforded them, for in a number of traverses through the range the tracks of several young animals were noticed. The increase would be much more rapid if more determined efforts were made to exterminate the timber wolves which inhabit the same region and are the chief natural enemy of the buffalo.

AGRICULTURE.

In the Salt Plain portion of this region, successful efforts are being made at ranching and farming by the Roman Catholic Mission. Barley, oats, and a variety of vegetables are successfully grown and about eighty head of cattle have been raised. Horses belonging to the residents of Fort Smith and Fitzgerald range

over the plain the whole year round and owing to the excellence and variety of the feed it is unnecessary to provide hay for the winter months. Horses that winter on the range are in splendid condition in the spring.

Flora.

A collection of grasses was made on the Salt plain and adjacent country and submitted to Mr. James Macoun for determination. The list is as follows:

Grasses.

Phalaris arundinacea L.	Reed Canary Grass.
Stipa canadensis Poir.	Feather Grass.
Sporobolus Richardsonis (Trin.) Merrill.	
Calamagrostis neglecta (Ehrh.) G.M.S.	
Koeleria cristata (L.) Pers.	
Spartina gracilis Hook.	Slough Grass.
Beckmannia erucæformis (L.) Host.	
Poa crocata Michx.	Meadow Grass.
Glyceria nervata (Willd.) Trin.	Manna Grass.
Puccinellia airoides (Nutt.) Wats and Coult.	
Bromus ciliatus L.	
" *inermis* Leyss. (Introduced).	Bromus Grass.
Agropyrum Richardsonii Schrad.	
" *tenerum* Vasey.	Blue-joint.
Hordeum jubatum L.	Squirrel-tail Grass.
Triticum pratense L.	Wheat.
Elymus Macounii Vasey.	
" *dasystachys* Trin.	Wild Rye.

Other Species than Grasses.

Triglochin maritima L.	Arrow Grass.
Carex?	Sedge.
Juncus balticus Willd.	Rush.
Scirpus campestris Britt.	Club Rush.
Delphinium glaucum Wats.	Larkspur (poisonous to cattle).
Vicia americana Muhl.	Wild Vetch.
Lathyrus ochroleucus Hook.	Wild Pea.
Hedysarum boreale Nutt.	
Companula rotundifolia L.	Harebell.
Galium boreale L.	Northern Bedstraw.
Achillæa Millefolium L.	Yarrow.

GENERAL GEOLOGY.

Since almost the whole region is underlain by horizontally bedded sediments and covered by a thick sheet of soil and drift, the stratigraphical succession of the rocks has not been completely worked out and our knowledge of the geology is based on the sections exposed at the following points: (1) Peace river between Little rapids and Peace point; (2) La Butte on Slave river; (3) Stony islands and Caribou island on Slave river; and (4) the escarpment at the brine springs of Salt river.

These sections show that the whole area is underlain by sedimentary rocks of middle Devonian age, which rest on a floor of Pre-Cambrian granite. The contact with the granite is exposed at two or three points on Slave river south of Fitzgerald, and the boundary between the two series follows more or less closely the valley of Slave river, being on the west side of the river at the mouth of the Peace, and between Stony islands and Fort Smith.

Peace River Section.

This section is exposed on the banks of Peace river for about 18 miles in cliffs which rise 20 to 60 feet above the level of the river. The lowest bed exposed is of gypsum, the thickness of which is variable but has an exposed maxi-

mum of 50 feet. The next overlying bed is a fractured and broken dolomite from 10 to 30 feet thick, above which is an argillaceous, sometimes sandy limestone containing fossils. Overlying all is the drift from 5 to 20 feet in thickness.

The beds undulate in both sharp and gentle folds and in one place are bent into a sharp anticline with dips on either limb of 60 degrees. The strike of the folds is not constant but varies widely.

In seeking for the cause of such a disturbed and irregular structure both at this section and elsewhere, it was evident at once that the disturbance of the beds could not possibly be connected with any orogenic movement of great magnitude, but was local in its effect and apparently confined to these particular beds. Certainly there is no evidence elsewhere throughout the region of the great plains of the operation of mountain-building forces producing such sharp folds as those indicated by dips of 60 degrees. The solution of this problem was found in the gypsum itself. At certain of the outcrops of gypsum rounded cores of anhydrite were noted in the gypsum. These cores showed a scaly rim of gypsum where the anhydrite by the absorption of water was altering to gypsum. At other localities thin beds of anhydrite are interbedded with gypsum. These facts suggest that some of the layers of gypsum, if not all of them, were originally anhydrite which by the accession of two molecules of water became altered to gypsum. In process of this alteration there would be an increase in the volume of the beds by 33 per cent. This increase causes horizontal as well as vertical expansion. The horizontal expansion results in folding of the beds and both together would probably cause the fracturing and brecciation of the overlying beds of limestone; for almost everywhere that the gypsum and the overlying limestone beds were exposed the limestone was found to be so fractured and brecciated, in places for only a vertical distance of 10 feet, but in other localities for as much as 40 feet.

Two localities in this section yielded fossils. From a point on the south shore near the foot of Little rapids and in a limestone bed about 30 feet above the gypsum the following fossils were obtained: *Spirorbis* sp., *Atrypa reticularis*, *Schizophoria iowensis*, *Cyrtinia curvilineata*. The same group of fossils were collected on the north shore at the head of the rapids from a bed occupying about the same horizon relative to the gypsum. They indicate an horizon of middle Devonian age.

La Butte Sections.

The sections at La Butte are exposed on the west bank of Slave river, one directly opposite, and the other a few miles farther downstream to the north.

The southern of these two sections is exposed in a low cliff rising about 35 feet above the water. The cliff shows the following section from the bottom upwards: (1) thin-bedded, grey limestone, 10 feet; (2) brecciated limestone impregnated with bitumen, 6 feet; (3) pebbly limestone, 10 feet; (4) massive limestone containing fossils, 5 feet.

The beds are undulatory with dips up to 15 degrees, and this together with the fact that one of the beds has been fractured and brecciated would suggest the presence of a bed of gypsum beneath. Pre-Cambrian granite is exposed to the southeast within a few hundred yards.

From the uppermost limestone bed (4) the fossils *Atrypa reticularis*, *Martinia sublineata*, and two species of *Orthoceras* were obtained indicating a middle Devonian age.

The northern of these two sections shows 10 feet of gypsum, overlaid by 20 feet of fractured and broken limestone similar to that on Peace river. The gypsum is thin bedded and impure, and contains narrow bands of selenite, satin spar, and white and bluish gypsum. The beds undulate slightly.

Stony Island Sections.

A number of good exposures occur on the banks of Slave river between Stony islands and Caribou island 12 to 20 miles above Fitzgerald. Most of these sections show the contact between the Pre-Cambrian and the Palæozoic.

The section at Stony island is best seen on the westernmost of this group of islands and shows the following succession from the base upward: (1) coarse-grained porphyritic granite much weathered and fractured on its upper surface; (2) conglomerate, containing mainly fragments of underlying granite and passing upwards into a sandstone, about 8 feet; (3) dark grey, dolomitic limestone passing upward into a lighter coloured, massive limestone. The limestone contains a thin seam, one-half to one inch thick, of black bituminous shale. The upper beds of this section have been used locally in making lime.

The Caribou Island section is best seen on the east side of the river near the head of Caribou island. The section shows at the base a siliceous hornblende granite, much jointed, fractured, and decomposed. Over this is an arkose about 10 feet thick made up of angular granite fragments, becoming finer grained towards the top and passing gradually upwards, without any abrupt division into a dark grey dolomitic limestone which is only exposed beneath the drift for a thickness of 6 feet.

Both here and at Stony islands the beds have a very slight dip and occupy depressions in the old granite surface, depressions which have a depth of as much as 50 feet, suggesting that the relief at the time of deposition of these beds was not very different from the relief at the present time in the adjacent Pre-Cambrian area.

Salt River Sections.

The Salt River sections are very imperfectly exposed in the escarpment which overlooks Salt river at the brine springs. The escarpment is from 150 to 200 feet high and extends from the brine springs at the forks of the river south and then southeastward in one direction for many miles, and westward in the other direction across Little Buffalo river. A complete section is not exposed anywhere south or east of the forks, but from the fragmentary sections examined it was evident that the lower part of the escarpment is occupied by gypsum, while the top consists of a bed of dark grey dolomitic limestone in which no fossils were noted. At one place about 50 feet of impure gypsum is exposed in some broken down cliffs, while at another point on Salt river southwest of Fitzgerald, 20 feet of thin-bedded gypsum is overlaid by dark grey dolomitic limestone. The gypsum is grey, white, and sometimes greenish or pink in colour. The last variety seems to contain some sodium chloride or common salt and on exposure becomes coated with efflorescent crystals of this mineral.

Springs rising from the base of the escarpment, which deposit common salt, are described later. Associated with these, however, are other springs which, on their waters coming in contact with vegetable matter, deposit a yellowish, calcareous tufa over areas several square yards in extent. The springs which are still flowing deposit a soft unconsolidated tufa, but, at points where these springs have ceased to flow, the tufa is hardened to a porous honeycombed rock which still retains the impressions of stems, roots, and leaves of plants.

Other Sections.

North of Fort Smith on Slave river, the Palæozoic rocks are only exposed at two points, and each of the outcrops is very small. At Bell rock, a square, massive looking cliff 7 miles below Fort Smith, a yellowish, brecciated limestone

is exposed. In excavating for certain foundations at this point, a soft decomposed gypsum was found to underlie the limestone. A second exposure occurs on the point on the east side of the river immediately below point Ennuyeux. This exposure shows at low water about 4 feet of thin-bedded, grey, impure gypsum underlying a fossiliferous, grey, shaly limestone. The beds undulate slightly, but the overlying limestone shows no sign of brecciation. The fossils obtained from this locality, namely: *Favosites cf. hamiltonae*, *Atrypa spinosa*, *Martinia cf. meristoides*, *Martinia cf. sublineata* indicate a horizon of middle Devonian age.

ECONOMIC GEOLOGY.

The only minerals of economic importance known to occur in this area are gypsum and salt. Search was also made for potash in the gypsum horizon but this proved fruitless and the results obtained were negative.

Gypsum.

At almost all the outcrops of the Palæozoic rocks in the area an important deposit of gypsum occurs. In other places where no outcrops occur, the presence of gypsum was suspected by the pitted and broken nature of the surface, which is so characteristic of a region underlain by gypsum. How much of the region is actually underlain by gypsum, it is difficult to say, but the area must be very great and can probably be measured in hundreds of square miles.

The thickness of the beds is variable and it is very likely in certain portions of the region they may be absent altogether. Nowhere is a complete section of the beds exposed, and, although in most outcrops the top is visible, the base is never seen. A maximum thickness of 50 feet is exposed at two points, namely, Peace river at Little rapids, and in the escarpment at the brine springs of Salt river. In other localities thicknesses of 10 or 20 feet are exposed.

No attempts have been made to work any of the gypsum deposits because of their remoteness from settled districts where gypsum products could be used, and indeed no claims have as yet been taken up on them. Some of the outcrops could not be worked economically because of the depth of overlying material, but others have not this disadvantage. The exposures on Peace river are the most favourably situated in this respect, while those in the escarpment at the brine springs could also be easily developed.

On Peace river gypsum is exposed on both banks of the river almost continuously for a distance of 15 miles or from Little rapids to a point 5 miles below Peace point. The exposed thickness varies from a few feet up to a maximum of 50 feet, the latter occurring on the south side of the river at the foot of the rapids. The gypsum is usually white and massive. In places it is earthy and thin bedded or holds narrow bands of dolomitic limestone. Selenite is rare, but thin veins and beds of satin spar are common. Anhydrite is occasionally present in rounded nodules or in thin beds. Overlying the gypsum is a fractured and broken bed of limestone, but since the structure of the beds is undulatory the gypsum is frequently brought up to the top of the cliffs and has no cover except the drift, the limestone having been removed by erosion. The drift varies in thickness from 5 to 15 feet and when the gypsum is covered only by the drift the conditions are most favourable for the economical mining of the beds. Such conditions occur in a number of localities in the section, particularly on the north side of the river.

Judging by the character of the surface back from the face of the cliff, gypsum must extend back from the river for a considerable distance. Taking an exposed length of 15 miles along the river and an average thickness of 15

feet of gypsum and assuming that the beds extend back from the river for at least a distance of a quarter of a mile on either side of the river, the quantity of gypsum in the Peace River section is at least 217,000,000 tons. A considerable proportion of this is very favourably situated for mining on account both of its location and the thin overburden of drift.

On Slave river, gypsum outcrops on the west side of the river a few miles below La Butte. The section shows about 10 feet of somewhat earthy, thin-bedded gypsum of white, grey, or bluish colour. The beds are traversed by thin seams of selenite and satin spar. They are, however, overlaid by about 20 feet of brecciated limestone. This, together with the fact that the beds would be below the river-level at the high water stage, would make the economical working of them somewhat difficult.

Gypsum outcrops again on Slave river immediately below point Ennuyeux, where a thickness of about 4 feet of thin-bedded, impure gypsum is exposed near the water-level at a medium stage of water. The same disadvantages as hold in the last-mentioned outcrop would prevent the easy mining of the beds at this locality.

Gypsum is also said to occur at Bell rock 7 miles below Fort Smith beneath the brecciated limestone of which the rock is built. The escarpment west and south of the brine springs of Salt river shows sections of gypsum beds at several points.

About 4 miles south of the brine springs at the forks of Salt river, cliffs of gypsum are exposed in the face of the escarpment. The escarpment here forms a deep bay and is 150 to 200 feet in height. It is heavily wooded and as a rule rises out of Salt plain with an easy slope to the upper plain. Several streams cut through the face of the escarpment and a number of springs rise from its base. These springs are not briny though they are milky white in colour from suspended calcium sulphate. This soon settles and the water becomes pale bluish in colour. At the locality mentioned cliffs of gypsum half a mile in length appear and are visible by their whiteness from some distance out in Salt plain. The cliffs are in a ruinous state and are deeply fissured and broken down, and the base strewn with freshly detached masses of gypsum and a tangle of fallen trees. The top of the escarpment also shows many recent cracks and deep sink holes. The cliffs show 40 to 50 feet of thin-bedded gypsum with occasional narrow layers of anhydrite or beds of dolomite. The gypsum is white or greyish and is disposed in horizontal beds. On the surface it crumbles to the powder gypsite and this is carried away by the streams and secondarily deposited farther down.

North of this locality the gypsum appears to decrease in thickness and is there seen to be overlaid by beds of grey crystalline dolomite. Gypsum was again observed in the face of the same escarpment at a point about 8 miles southwest of Fitzgerald where Salt river flows along its base. The section here shows about 20 feet of thin-bedded white gypsum overlaid by about 10 feet of dolomitic limestone.

The escarpment is known to extend more or less continuously from the last-mentioned locality in a sinuous line northwestward for about 40 miles or beyond Little Buffalo river. Since the escarpment is probably caused by erosion where hard resistant beds overlie softer and more soluble strata, it is reasonable to suspect that, as the strata of the escarpment are horizontal, gypsum will be found to occupy the base of the escarpment throughout the greater part of its length. This suspicion is borne out by the character of the surface on the top of the escarpment, which is broken and pitted with sink holes in a way characteristic of a gypsum region.

Salt.

No evidence was obtained to indicate that beds of rock salt occur anywhere in this region, although it is possible that such beds may be present. The conclusion was arrived at that the source of the salt in the brine was to be found not in solid salt beds but rather in crystals of this mineral disseminated through the gypsum. That the gypsum does sometimes contain some sodium chloride is shown by the efflorescences of this mineral that appear on some specimens of the gypsum on its exposure to the atmosphere. Such instances were found in the coloured gypsum at the Snake Mountain springs.

A number of brine springs rise at the base of the escarpment which lies to the west and south of the forks of Salt river. These springs have been known for years and were described by Sir John Richardson, Captain Back, McConnell, and the writer. There are four important groups of springs, from each of which salt is deposited. Salt, however, is gathered only from two of these localities, by the Hudson's Bay Company and the Roman Catholic Mission.

In each of the springs the water rises among an accumulation of boulders near the base of the escarpment and flows thence into shallow circular basins, after which the water trickles away through barren salt-encrusted clay flats to the river. On evaporation, salt is precipitated from the brine in the basins and is gathered at these points. The basins are usually about 15 or 30 feet in diameter and are in many cases surrounded by a natural dyke of clay or gravel 1 to 3 feet high. The bottoms of the basins are floored with a deposit of salt of varying thickness. In other cases hillocks of salt 12 or 15 feet in diameter and up to 2 feet in height are formed at the springs.

At the time of our visit to these springs on August 26 and 27, the flow was very small, being rarely as much as 4 gallons per minute at any one spring. The flow, however, is said to be considerably greater in the springtime when the surface water is melting and running off from the region. The temperature of the brines on emission varied from 35 to 40 degrees Fahrenheit, with the atmosphere at 60 to 70 degrees, and many of them were saturated solutions of sodium chloride.

Altogether about 4 tons of salt are collected annually from these springs for the use of the trading posts and missions of the Mackenzie River district.

Samples of brine were taken from three localities and analysed in the laboratory of the Department of Mines. The data on the samples are as follows:

No. 1 locality, Hudson's Bay springs at the forks of Salt river; taken August 21, 1916. Contains in 1,000 parts by weight:

Analysis of Water from Hudson's Bay Springs.

Ions		Hypothetical combination	
Potassium	0·5	Potassium chloride	0·9
Sodium	101·5	Sodium chloride	258·0
Calcium	1·2	Calcium sulphate	4·1
Magnesium	0·2	Sodium sulphate	0·4
Chlorine	157·7	Magnesium chloride	0·8
Sulphuric acid (SO_4)	3·1		
	264·2		264·2

Temperature of air on collection................62°F.
Temperature of brine..........................40°F.
Specific gravity at 65°F........................1·204
Flow about 1½ gallons per minute from each of eight springs.

No. 2 locality, Mission springs, about 6 miles south of the forks of Salt river; taken August 26, 1916. Contains in 1,000 parts by weight:

Analysis of Water from Mission Springs.

Ions		Hypothetical combination	
Potassium	0·4	Potassium chloride	0·8
Sodium	100·8	Sodium chloride	256·3
Calcium	1·2	Calcium sulphate	4·2
Magnesium	0·2	Sodium sulphate	0·2
Chlorine	156·6	Magnesium chloride	0·8
Sulphuric acid (SO_4)	3·1		
	262·3		262·3

Temperature of air on collection.............70°F.
Temperature of brine.......................35°F.
Specific gravity at 65°F.....................1·204
Flow about 3 gallons per minute.

No. 3 locality, Snake Mountain springs, about 2 miles east of Mission spring; taken August 29, 1916. Contains in 1,000 parts by weight:

Analysis of Water from Snake Mountain Springs.

Ions		Hypothetical combination	
Potassium	0·4	Potassium chloride	0·8
Sodium	100·7	Sodium chloride	256·0
Calcium	1·2	Calcium sulphate	4·2
Magnesium	0·2	Sodium sulphate	0·2
Chlorine	156·4	Magnesium chloride	0·8
Sulphuric acid (SO_4)	3·1		
	262·0		262·0

Temperature of air on collection.............58°F.
Temperature of brine.......................40°F.
Specific gravity at 65°F.....................1·202
Flow about 4 to 5 gallons per minute.

In recalculating these analyses we find that sodium chloride constitutes in each sample over 97·6 per cent of the total solids. The percentage of dissolved matter in the brine, namely over 26 per cent, indicates practically a saturated solution of salt at that temperature.

Potash.

The possibility of finding salts of potassium associated with the gypsum beds of this region was a point that was always kept in view in the course of the season's work, and was in fact one of the primary objects of the investigation. Rumours had been circulated last spring that specimens of a mineral containing a high percentage of potash had been found somewhere in this region; and, since the only extensive deposits of potash in Europe are associated with beds of gypsum, anhydrite, and rock salt, it seemed not improbable that similar potassium salts might be found to be associated with the rocks of that character in this region. Potassium salts are very soluble indeed and it was recognized that natural outcrops of either potassium chlorides or sulphates would not be likely to occur in a

region of such humidity as that of northern Alberta; and since it was not advisable for the Geological Survey to conduct any deep drilling operations on the gypsum beds, the investigation of possible sources of potash was necessarily confined to the collection and analyses of the underground waters which reach the surface at a number of points throughout the region.

The locality in which potassium salts were most likely to be found was at the brine springs of Salt river. Three samples were collected from this locality, the analyses of which are given on a previous page. Recalculating the hypothetical combinations out to percentages of total solids we find that No. 1 contains 0·34 per cent of potassium chloride; No. 2, 0·31 per cent; and No. 3, 0·30 per cent of the same mineral.

Two other samples of water were taken, the analyses of which were made in the laboratory of the Department of Mines and are given below. No. 4 is from a depth of 268 feet in the bore-hole put down at Vermilion chutes on Peace river, and No. 5 is water from a natural spring at Sulphur point on the south shore of Great Slave lake.

The analyses are as follows:

Analyses of Waters from Vermilion Chutes and Sulphur Point.

Ions	Parts per million.	
	No. 4	No. 5
Chlorine	8,340	213
Sulphuric acid (SO_4)	100	1,500
Bicarbonic acid HCO_3	......	370
Calcium	289	480
Magnesium	189	130
Sodium	4,760	200
Potassium	12	trace
Total	13,690	2,892
Hydrogen sulphide	400	42

Hypothetical combination	Parts per million		Percentage	
	No. 4	No. 5	No. 4	No. 5
Potassium chloride	22	.....	0·16	......
Sodium chloride	12,100	351	88·37	12·14
Magnesium chloride	739	191	5·39	6·60
Calcium chloride	688	.....	5·04	......
Magnesium sulphate	......	644	......	22·27
Calcium sulphate	143	1,220	1·04	42·18
Calcium bicarbonate	......	486	......	16·80
	13,692	2,892	100·00	100·00

Specific gravity at 18° C. No. 4, 1·011; No. 5, 1·002.
Flow of No. 4 on July 13, 1916, 42 gallons per minute; temperature 42°F.
Flow of No. 5, on Aug. 4, 1916, about 2 gallons per minute.

In all these analyses the proportion of potassium is low, and certainly not high enough to make it possible to extract the potassium in a commercial way even if the volume of water from each of these localities were very much greater; nor is there anything to indicate that the waters of these springs flow through rocks containing an unusual proportion of potash. There is no evidence, therefore, of the presence of potash in commercial quantities in the vicinity of the points where these samples were collected.

Oil and Gas.

During the summer of 1916 boring operations were conducted at two different points on Peace river, namely, at a point about 17 miles below Peace River Crossing and at the upper end of Vermilion chutes.

At the former locality the drill was sunk to a depth of over 1,100 feet from the surface, presumably entirely in Cretaceous strata consisting of sandstones and shales. At 857 feet a flow of heavy black oil was struck, yielding about a barrel daily. This was cased off and the hole continued to a depth of over 1,100 feet when an exceptionally strong flow of gas was struck which wrecked the derrick and forced the drillers to suspend operations at least temporarily.

A sample of this oil was analysed in the laboratory of the Department of Mines by E. Stansfield; his report follows:

Sample No. 823. Crude petroleum. Collected by Charles Camsell of the Geological Survey on September 18, 1916, from McArthur well, Peace river, 17 miles below Peace River Crossing.

The sample was a dark viscous oil, with an odour resembling kerosene, from which a considerable amount of water had separated out at the bottom of the bottle. This water was neglected.

It was found to be impossible to make a satisfactory fractional distillation of the crude oil, on account of trouble with bumping and frothing. A preliminary distillation was, therefore, made; this distillation was ultimately carried out under reduced pressure as far as was possible in a glass flask, a sticky black pitch remaining in the flask. The oil obtained by this preliminary distillation was fractionated in an Engler apparatus.

The results obtained follow:

Solubility of crude oil in benzene, practically completely dissolved.
" " " " in gasolene, 5 per cent by weight insoluble (soft asphalt, dirt and tarry matter).
" " " " in alcohol-ether, considerable insoluble matter.
Specific gravity of crude oil, 0·984 at 15·5°C.
Flash point, Pensky-Martens close test 59°C.
Fire point, about 127°C.

Preliminary distillation of 201 grams of crude oil gave:
136 grams of oil distillate of 0·902 sp. gr. or 67·7 per cent by weight and 73·9 per cent by volume.
46·3 grams of pitch residue or 23·0 per cent by weight.
18·7 grams of water and loss or 9·3 per cent by weight.

Fractional distillation in an Engler apparatus of 100 c.c. of oil distillate gave at:
140°C. first drop.
140° to 150°C. gasolene and kerosene fraction, 2 per cent by volume, 0·642 sp. gr. or 1·5 per cent crude oil.
150° to 300°C. illuminating oils, etc. 32·5 per cent by volume, 0·834 sp. gr. or 24·0 per cent crude oil.
Residue, lubricating oils, etc. 64·5 per cent, or 48·4 per cent crude oil.

On a large scale the preliminary distillation could be carried further than in the small scale laboratory experiments, and larger yields obtained.

Calorific value of crude oil, 9·730 calories per gram. or
17,520 B. T. U. per lb.
Sulphur in crude oil =4·9 per cent.

At Vermilion chutes a drill hole was driven to a depth of 860 feet, but at that depth an accident happened to the stem of the drill which prevented the hole being driven any farther and drilling ceased without having struck oil.

The rocks cut in this drill hole are Devonian limestones and shales which have a slight dip to the westward. The upper beds are porous and impregnated with bitumen, and at two or three points in the neighbourhood heavy black oil comes to the surface in springs. A strong flow of water yielding 42 gallons per minute and charged with hydrogen sulphide was struck at a depth of 268 feet below the surface. The water on analysis yielded the following results:

Analysis of Water from Vermilion Chutes:

Ions	Parts per million
Chlorine	8,340
Sulphuric acid (SO_4)	100
Bicarbonic acid (HCO_3)	....
Calcium	289
Magnesium	189
Sodium	4,760
Potassium	12
	13,690
Hydrogen sulphide	400
Specific gravity at 18°C	1·011

A spring of natural gas is situated at Tar island on Peace river about 25 miles below Peace River crossing. The gas rises with salt water and some tar from among the gravel and boulders at the upper end of the island. The flow of gas was roughly calculated to be about 3 or 4 cubic feet per minute. Samples of this were taken and submitted to the Department of Mines and to Arthur D. Little, Limited, of Montreal, for analysis. The first sample became contaminated with air before analysis, but the one submitted to Arthur D. Little, Limited, showed the following composition:

Analysis of Gas from Tar Island.

Carbon dioxide	0·8	per cent.
Oxygen	0·3	" "
Methane	98·0	" "
Nitrogen	0·9	" "
	100·00	

Specific gravity compared with air, 0·55.

ATHABASKA RIVER SECTION, ALBERTA.

(*F. H. McLearn.*)

The occurrence of tar sand and gas and the possibilities of the presence of oil, have, for a long time, attracted attention to this region. A few writers have described it, but the report of R. G. McConnell[1] is the most comprehensive. During the field season of 1916 a re-study of the section was made from Athabaska to a point about 8 miles below Calumet river, a distance of 286 miles, measured along the course of the river.

[1] McConnell, R. G., "Report on a portion of the district of Athabaska", Geol. Surv., Can., 1893.

CHARACTER OF THE DISTRICT.

The region as a whole consists of a number of plateau-like surfaces which, along the river, become lower in altitudes northward. They are underlain by gravel, sand, and clay, and are poorly drained, with large areas of swamp and muskeg. The country is wooded with spruce, jack-pine, poplar, and a little birch.

Below McMurray, the river presents more mature features than above, occupying a broad valley with gentle side slopes and with a low grade. Above McMurray, the valley is narrower, and has a steeper grade. From Grand rapids downstream numerous rapids are formed by unreduced concretions from the Grand Rapids formation and below Crooked rapid numerous ledges of limestone form rapids and cascades.

Much of the land is undeveloped, owing, in part, to the prevalence of swamp and muskeg and also to its isolation. What little settlement there is is due to the fur trade and the use of the Athabaska for many years as a trade route to the north. Athabaska is the nearest point on the river to Edmonton, being situated at the apex of a great bend to the south. Pelican, once the site of a Hudson's Bay Company post, is located where the portage to the Pelican and Wabiskaw canoe route begins. House River, consisting of a small store and a few cabins, is situated at the southwest terminus of the pack trail to McMurray and this point is also the lower limit of navigation on the upper part of the river. McMurray is a large settlement and townsite at the confluence of the Clearwater with the Athabaska and lies at the head of steamboat navigation on the lower part of the river. With the completion of the railway from Edmonton and the use of the river again as a trade route, it should increase in importance. McKay, a small settlement 33 miles below McMurray and an old Hudson's Bay Company post, is still of some importance as a trading centre. It is situated near the mouth of McKay river, which, together with the Moose Lake trail, affords a means of communication with the interior trapping country.

GENERAL GEOLOGY.

Table of Formations.

Era	Period	Thickness	Formation
Quaternary			Gravel, sand, and clay.
Unconformity			
Mesozoic	Cretaceous	1100+	La Biche formation.
		35	Pelican sandstone.
		90	Pelican shale.
		280	Grand Rapids formation.
		275	Clearwater formation.
		110 to 180+	McMurray formation.
Unconformity			
Palæozoic	Devonian	220+	Limestone series.

Limestone Series. The Limestone series first appears at Crooked rapids and outcrops down river, rising in places in low cliffs supporting the overlying tar sands and in places sinking below the river. It is difficult to construct a stratigraphical column of the strata so occurring, since the outcrops are not continuous, the strata occur in low folds rarely showing more than 20 feet of beds at one place, definite horizon markers with which to correlate the individual outcrops are few, and there is no type section in which all the strata are exposed. It has been possible, however, to construct such a column for the strata between Moberly rapids and McKay, a distance of 34 miles:

Devonian Section between Moberly Rapids and McKay.

	Feet	Inches
Light green and yellow, somewhat shaly and friable limestone with a few hard layers	48	0
Massive shell limestone with *Stromatopora*	4	0
Yellowish, shaly limestone	2	4
Massive shell limestone with *Stromatopora*	2	0
Light greenish and yellowish, shaly, friable limestone	40	0
Massive, shell limestone with *Stromatopora*	6	0
Hard, bryozoa limestone with horizontal partings	12	0
Shaly, light greenish limestone with small *chonetes*, etc	7	6
Massive shell limestone	3	0

The 40 feet of massive and layered, fossiliferous limestone, which underlies the tar sands below McKay, does not correspond to the above section and must be added to the general column. Likewise, the 15 feet of calcareous shale overlying 40 feet of fossiliferous limestone below Calumet river on the west bank adds to the total section exposed.

McMurray Formation. The tar sands of this formation outcrop in numerous steep cliffs from Boiler rapids, all the way down the river to the end of the section. For various reasons the term "tar sands" is not applicable as a formation name. It is, first of all, a lithological term and, moreover, the actual limits of tar impregnation are uncertain. Dakota is also unsatisfactory, since the exact age of the sands is not established. It is better, therefore, to give the formation a new name and to define its upper limit, not on the fortuitous limits of asphaltic content, but on the change from freshwater to marine conditions. The top is placed at the base of a bed of green sandstone, in places somewhat argillaceous, immediately above which the marine fauna of the Clearwater appears and below which the sands of the McMurray appear carrying a small invertebrate fauna of freshwater origin. The formation is prevailingly arenaceous and of rather coarse grain, the uppermost part lies horizontal, and varies from massive to thick-bedded, but is never thin-bedded. The remainder and greater part of the formation is, in many places, cross-bedded on a very large scale with the beds dipping from 5 to 40 degrees. This part may be bedded above by intercalation of argillaceous sandstone or finer sandstone beds with the coarser sandstones, but it is always massive below. Sometimes conglomerate, and more rarely clay or shale, are found at the very base.

Clearwater Formation. The Clearwater shales and sandstones first appear about 5 miles below Grand island and gradually rise downstream, forming 45 to 60 degree slopes below the cliffs of the Grand Rapids sandstone. The formation is made up of soft, grey shales, black shales, grey and green sandstones, together with some hard concretionary layers. Some beds are highly fossiliferous and a marine fauna ranges throughout the formation.

Grand Rapids Formation. The sandstone of this formation begins to outcrop about 3 miles above the Joli Fou rapid and is exposed at all the bends as far as Grand rapids. Below Grand rapids it forms almost continuous cliffs for miles.

The lower concretionary part is exposed at the fall in Grand rapids and from there downstream forms a cliff at the edge of the river. Above it, separated by two benches, rise the two remaining cliffs of the formation. The conditions of deposition varied considerably, and the incorporation of these beds into a single formation unit, is based on their prevailing arenaceous character. The lower concretionary member is marine, the large concretions below Grand rapids carrying marine pelecypods. The upper part is of subaerial origin, as demonstrated by the presence of small coal beds and vertical rootlets below the coal.

Pelican Shale. The Grand Rapids sandstone is overlain by black shale, carrying poorly preserved *Inoceramus.* The Pelican shale first appears near Stony rapids and downstream forms a low slope or bench between the Grand Rapids cliff below and that of the Pelican sandstone above. By the intercalation of thin sandstone and shale beds, the series grades upward into the Pelican sandstone.

Pelican Sandstone. The Pelican sandstone forms a low cliff in all the exposures from Stony rapids to Grand rapids. It is made up of cross-bedded sandstone, conglomeratic at the top. The presence of mud cracks points to subaerial conditions during a part of its deposition, but the thin bedding at the base and the presence of *Inoceramus*, although poorly preserved, at the top, show that marine conditions prevailed at both the beginning and the end of the time recorded by the sediments.

La Biche Formation. This thick formation is made up almost entirely of grey and black shale with layers of concretions at various horizons, the latter sometimes carrying fossils. It is the only formation outcropping between Athabaska and Pelican rapids. It forms low valley slopes and only outcrops at the bends or in scarps made by landslides.

STRUCTURE.

In reality, the Athabaska river exposes three sections: from Athabaska to point Brûlé it cuts a north-south section; from point Brûlé to McMurray a nearly east-west section; and below McMurray a north-south section.

The structure from Athabaska to point Brûlé is simple, consisting of a half-fold or homocline with a low south dip. From Grand rapids to Pelican rapids the rate of dip is about 5½ feet per mile, and north of Grand rapids the dip flattens considerably. But south of Pelican rapids to carry the strata to their position in the Athabaska bore-hole requires a dip of about 10 feet per mile. This greater dip below may be due, in part, to the southwest course of the river near Athabaska. Indeed the true dip is probably west of south, rather than directly south, and hence steeper on sections in the former than in the latter direction.

The section exposed between point Brûlé and McMurray is almost at right angles to the above and shows a low anticlinal structure (Athabaska anticline). The axis lies near Crooked rapids and the dips on either side are exceedingly low, only about 3 or 4 feet per mile.

Below McMurray the land on either side of the valley is low, so that the top of the McMurray formation soon ceases to be exposed in the cliffs. Since the bedding of this formation is not reliable for structural purposes, the dip cannot be accurately determined there. It probably does not depart very far from the horizontal, but may have a slight north or northeast dip. This section is best adapted for demonstrating the structure of the limestone and the nature of the unconformity.

In addition to sharing with the Cretaceous sediments of the above described Athabaska anticline and the long half-fold to the southwest, as a major structure, the limestone is warped into low domes of much smaller magnitude.

THE UNCONFORMITY BETWEEN THE DEVONIAN AND CRETACEOUS.

To some extent at least the limestone surface follows the folds of the limestone series. Where the actual contact is exposed between Moberly rapids and McKay it is always somewhere in the upper part of the 48 feet of shaly, light green and yellow limestone at the top of the section given on page 147. In the exposures just below McKay the limestone underlying the Cretaceous is different from that in the outcrops upstream. Below Calumet river, on the west bank, cream coloured, calcareous shale outcrops nearest to the tar sands and cannot be far from the contact. This probably corresponds to the shale which, in the bore-holes of the Athabaska Oils, Limited, 8 miles upstream, is reported to underlie the tar sands. It can thus be seen that when followed far enough the contact overlaps on other horizons.

ECONOMIC GEOLOGY.

Oil.

Search for oil in the Athabaska region involves two distinct problems—the possibility of its occurrence in the sands at the base of the Cretaceous (tar sands) and in the underlying limestone series.

In regard to the source of the bituminous products in the sands, two theories may be considered. The first of these, proposed by numerous writers, seeks an origin in the underlying Limestone series. Along with this, however, should be considered a second and nearer source, one which may be found in the overlying black shales of the Clearwater formation. This theory dispenses with a requirement of the first, i.e., the necessity of fissures, through the limestone, connecting the bituminous shales of the older Limestone series with the McMurray beds above. Such fissures are rarely, if ever, observed in the outcrops. Ells notes the general absence of faulting and interprets an upwelling through a "main inlet or inlets" rather than at many points. Derivation from the overlying shales, i.e., the second theory, must meet with the quantitative requirement that the black shales of the Clearwater be thick enough to furnish the amount of bituminous products in the tar sands.

An important economic problem is the segregation and concentration of the bituminous products, whatever their source, into oil pools and gas sands. It is a common experience in oil and gas deposits of the world to find that a circulation has been set up, whereby the various products become arranged vertically in order of specific gravity, with water below, then oil, and then gas above. Thus water would be found in the hollows or basins, gas on the very crest of the arches or vaults of the containing reservoir, and oil in an intermediate position, but usually high in the domes or other vaulted structure. Where the reservoir is "dry," however, the oil tends to collect in the basins. Too much stress cannot be laid on the fact that the presence of gas in a reservoir is not necessarily indicative of the presence of oil. Indeed, any one, or any two, as well as all three of the substances, oil, gas, and water, may exist in a reservoir.

Considering first the central and southwestern part of the district, from Athabaska to McMurray, it must be stated, at the outset, that no liquid oil has so far been found, nothing more than the asphaltum or at best semi-liquid maltha content of the tar sands. The discussion below, therefore, relates to the probable conditions under which liquid oil would collect, if present. The most pronounced structure in the section is the low broad Athabaska anticline and the long half-fold to the southwest. Below Boiler rapids the McMurray sands outcrop and are impregnated with asphaltum and the gas spring at point Brûlé is probably

due to the escape of gas from this horizon which is here under thin cover. The gas escaping at point La Biche comes from either the Clearwater or the McMurray formations. The only knowledge we have of the latter formation, under deep cover, is that obtained from the logs of the wells at Pelican and Upper Pelican. The McMurray at Pelican is overlain by about 750 feet of later sediments and is 59 miles from the outcrop. The material at this depth, therefore, cannot be said to have undergone any surface alteration. The wells show much gas and also asphaltum or "asphaltic-like maltha" little different from the asphaltum of the surface outcrops. No liquid oil is present and the rock is "dry". This shows, first of all, that there is little or no segregation of asphaltum or gas and this lack of segregation may be due to the high viscosity of the former. It also shows that there is good reason to believe that the anticline and half-fold as far down the dip as Pelican is gas-bearing rather than oil-bearing. If there has been segregation of liquid oil from the gas and the disseminated heavier residues, it must be below the gas. As far as the homoclinal structure is effective, therefore, the possibilities for the occurrence of oil southwest of Pelican (i.e., down the dip) are better than for its occurrence north or northeast of Pelican (i.e., up the dip). However, owing to the low dip, small oil pools might form anywhere along the Cretaceous-Devonian unconformity where irregularities in the contact would form basin-like depressions. But these could not be located under cover, and, at best, would be uncertain in location and size. The most favourable conditions would exist where both structure controls, that of homocline and irregular contact, acted together.

Turning to the northeastern part of the district, the wells of the Athabaska Oils, Limited, opposite the mouth of Dover river, are interesting since they record the presence of oil, although of low gravity (Beaumé). The wells are all shallow and the tar sands themselves outcrop, so that the conditions of cover do not exist. It cannot be denied, therefore, that this oil may have lost some of its more volatile constituents.

The structural relation is important, since the oil has here collected in a hollow of the Cretaceous-Devonian unconformity. This depression is 12 miles long in the direction of the river and opposite the mouth of Dover river, at the wells of the Athabaska Oils, Limited, has a depth of about 85 feet below the river and about 140 feet below the limestone rim. Exploration may well be extended over the whole of this basin and also over the smaller one succeeding it downstream. Oil in sufficient quantity and of sufficient liquidity to pump must be found to make this a commercial proposition.

This locality shows the tendency of the oil, when present, to collect in basins and this is just what would be expected in "dry" strata. It is unfortunate that the Cretaceous in this district is not folded into a pronounced synclinal structure that would form a basin for the reception of oil. Investigations in the region away from the immediate vicinity of Athabaska river should not neglect synclines, where present, unless they are found to be water-bearing at the horizon of the McMurray sands.

In the exploration of this district the kind of oil likely to be found should be taken into consideration. The theory has long been held that the tar sands represent a reservoir in which a large quantity of light petroleum was confined and that the asphaltum is a residue resulting from the distillation of this once fluid oil under exposure at the surface. It was thought that by getting away from surface leakage, the lighter material would be found unaltered. The government well at Pelican was put down to test this theory. But as already noted no liquid oil was found—only a viscous asphaltum or "asphaltic-like maltha" which clogged the drill and finally stopped operations. As there is sufficient cover here to imprison large quantities of gas, the asphaltum cannot be explained

by leakage. It follows that the asphaltic or at best semi-liquid maltha content is of wide extent, and that heavy bituminous material is characteristic of the horizon as a whole and is probably original. Heavy oil, therefore, rather than light oil is to be expected. Expectations of discovering oil in the district should not be biased by the old theory.

From McMurray downstream a number of wells have been put down into the Devonian limestone and some are situated on the small domes. Neither oil noı gas in appreciable quantity has, as yet, been reported from any of them.

Gas.

As already noted, the McMurray sandstone, under cover, carries gas in large quantity. Except, therefore, where the formation outcrops or is under light cover, the conditions are favourable for exploration. There is some reason to believe that the gas is not uniformly distributed through the sands and, therefore, large quantities must not be expected from every well put down.

The government well at Pelican and the No. 3 well at Upper Pelican both have a large flow. A sample taken by the writer from the former was analysed by Mr. E. Stansfield with results as follows:

CO_2	1·0 per cent.
O	2·9
Methane	83·5
N	12·6

Assuming "oxygen present is due to contamination with air" the composition would be:

CO_2	1·2 per cent.
Methane	97·0
N	1·8

The gas is "dry," consisting principally of methane.

The government well at Athabaska encountered gas in the La Biche shale and still gives a small flow. Other shallow wells in the same formation also give a small quantity of gas. Some wells show unimportant amounts in the Clearwater formation. A little gas has also been reported from the Devonian limestone series. Exploration, to date, indicated that the McMurray sandstone ("tar sands") is the only source of gas that promises to be of commercial importance.

Coal.

At Grand rapids lignitic coal is found at the top of the Grand Rapids formation. A thickness of 4 feet was measured on the west bank. It thins about a mile below Grand rapids, but is still present nearly 2 miles to the southwest, on Loon river, where 3 feet of somewhat shaly lignite outcrops on the southeast bank of the stream. Coal reappears at the same horizon, at point La Biche, where the following section is exposed at the top of the formation:

	Feet	Inches
Pelican shale	..	..
Coaly shale	0	10
Lignitic coal	0	7
Sandstone	..	..

A second seam occurs at the same locality 95 feet below the top of the formation. It is 2 feet 8 inches thick.

A few lenses of lignite have been found in the McMurray formation, but the prevailing cross-bedded structure of the latter records conditions unfavourable for the development of coal beds of any size or extent.

BLACK BAY AND BEAVERLODGE LAKE AREAS, SASKATCHEWAN.

(*F. J. Alcock.*)

The field season of 1916 was spent by the writer in continuing the exploratory and geological work begun in the summer of 1914, in the region north of lake Athabaska. Most of the season was spent in the region of Beaverlodge lakes, this being the district in which the iron deposits of the region are located, and the one which was considered most likely to lead to fruitful results in solving the geological problems concerning the succession and structure of the rocks of the region. Additional work was also carried out in the Black Bay area.

The route used in reaching the field was by way of Peace River crossing, to which point trains run twice a week from Edmonton. The party was outfitted at Peace River crossing and on June 6 started down the river in canoes. In five days Fort Vermilion was reached, a distance of 300 miles below Peace River crossing. Fifty miles below Fort Vermilion are the Vermilion rapids and chutes which form the only obstruction to navigation on the river by shallow-draft steamers for a distance of over 700 miles. A portage $4\frac{1}{2}$ miles in length was made here, over a wagon road on the southeast side of the river. Below the chutes the river flows smoothly to where it joins Slave river, the only exception being a short stretch of swift water at Little rapids which is easily run by canoes and steamers at highwater but which, late in the season, is too shallow to be navigated by the latter. The trip from Fort Vermilion to the head of Quatre Fourches channel, where Peace river is left in order to proceed to lake Athabaska, occupied six days. The Quatre Fourches is a narrow meandering channel about 40 miles in length with a slight current dependent upon the height of the water at the western end of lake Athabaska. When traversed in June its direction was towards the lake. Arrived at the mouth of the channel, a heavy wind and sea prevented crossing to Chipewyan, but in the evening the Dominion fire-patrol steamer *Rey* brought the party and outfit to Chipewyan, June 21.

The field work of the season consisted in studying the Pre-Cambrian succession in two areas north of lake Athabaska, in mapping the lakes north of Beaverlodge bay and the portage route leading from there to Black bay, and in making a more or less detailed geological map of this area. In returning from the field, a gasoline launch was secured from Mr. Colin Fraser at Chipewyan, which brought the party to McMurray on Athabaska river. A railway is under construction from Edmonton to McMurray, but 90 miles of steel still remain to be laid. The regular mail route by river to Athabaska was accordingly followed. This consists of a portage 80 miles in length from McMurray to House River to avoid the numerous rapids on Athabaska river, and by launch from there to Athabaska. Pack-horses were secured at McMurray which brought the outfit in four days to House River where a launch was already waiting and three more days completed the journey to the railway, the whole distance from Chipewyan to Athabaska having occupied twelve days.

Topography.

The topography of the region north of lake Athabaska is typical of the Laurentian plateau in general, though with slightly more relief than is displayed in most of that region. Lake Athabaska has an elevation of 690 feet; north of Black bay, the higher elevations reach a height of 1,500 feet above sea-level. In the Beaverlodge area, the highest elevation of the Beaver hills is 1,290 feet. Everywhere throughout the region the surface is rolling and hummocky with irregular ridges

having precipitous sides and separated by valleys usually occupied by lakes or muskeg.

Geological Succession.

The geological succession of the rocks of the region may be tabulated as follows:

Post-Cambrian	Recent	Beaches, bars, spits, dunes.
	Pleistocene	Till, moraine, sand-plains.
	Unconformity	
Pre-Cambrian	Athabaska series	Sandstone, arkose conglomerate, trap flows, sills, and dykes.
	Unconformity	
	Granites and gneisses	
	Intrusive contact	
	Tazin series	Quartzite, slate, dolomite, breccia, sericite, and chlorite schists.
	Unconformity	
	Gneissic complex	
	Intrusive rocks	Granites, gabbro, amphibolite, norite, diabase.

Granites and Gneisses. In mapping, it was not found possible to differentiate the granites and gneisses of the region, although they clearly belong to at least two different periods of intrusion. The greater part of them are younger than the rocks of the Tazin series, as is shown by their intrusive contact with the latter at most places. The existence of an older complex is shown, however, by several lines of evidence; granites are found at various places cutting foliated gneisses; at two different localities Tazin quartzite was found dipping off from a surface of gneiss; a few pebbles of gneiss were, in one locality, found in Tazin sediments; the fact that the dominant sediment of the Tazin series is quartzite implies the existence of an older acidic terrane. Though most of the gneisses are clearly igneous, the fact that some of them are graphitic and others garnetiferous, is suggestive of a sedimentary origin for at least part of the older complex.

Tazin Series. The name Tazin series was introduced by Charles Camsell for a group of rocks seen by him in his exploration journey in 1914 from lake Athabaska to Great Slave lake over the Tazin and Taltson rivers. The two areas north of lake Athabaska in which these rocks are most widely exposed, are the Beaverlodge Lakes and Black Bay districts. The succession in the former area may be summarized as follows:

Iron formation	925 feet
Dolomite and quartzite	5,900 "
Quartzite and schist	8,500 "

Quartzite. The dominant rock of the series in this area is a white quartzite, in places feldspathic, especially towards the base of the formation. It, locally, shows a red and white colour banding and contains small quantities of hematite.

There is no basal conglomerate. Shearing has changed considerable quantities of the rock into sericite schist.

Dolomite. Lying stratigraphically above the main quartzite area is a group of rocks consisting of dolomite, quartzite, and schist whose thickness could only be approximately determined. The dominate rock is dolomite which at one place forms a ridge including some of the most prominent hills of the area. The dolomite is interbanded with quartzite, but owing to deformation, the common structure seen is dolomite containing irregular masses of quartzite and areas of quartzite containing patches of dolomite. Metamorphism of the dolomite along the contact of the granite intrusive has resulted in the production of a light green amphibolite.

Iron Formation. The upper member of the group consists of an iron-bearing series, made up of white quartzite, banded, cherty, ferruginous quartzite and cherty quartzite, interbanded with hard, blue hematite. The quartzite is dense and hard and has been much fractured; concentration of the iron has been limited to small, local, well-leached patches.

In the region of Black bay, the Tazin rocks consist of a thick series of quartzites and chlorite and sericite schists overlain by quartzite and slate. The series is closely folded; the slates exhibit many drag folds but only an imperfect slaty cleavage. In the quartzites, ripple-marks are well preserved and mud-cracks locally. Friction breccias on a large scale are found at several points. The folding and faulting which the rocks have undergone render it difficult to determine the thickness of the series in this area, but it is to be measured in thousands of feet.

A band of sediments in the region between Sand and Big points presents features corresponding to the Tazin rocks of the other areas. The succession is as follows:

	Feet
Arkose, red and grey	400
Conglomeratic quartzite	20
Quartzite and slate	600
Grey feldspathic quartzite	400
Schist and slate with some quartzite	1,000
Schist and quartzite in alternate bands	1,800
Total	4,220

Athabaska Series. Unconformably overlying the granites and the Tazin rocks is a thick, clastic formation known as the Athabaska series. At most places it lies horizontally or with but low dip; in the Beaverlodge area, however, the series forms an open syncline with maximum dips of 40 degrees and pitching to the north; its thickness here is approximately 8,800 feet. It consists of thick-bedded sandstones, arkoses, and conglomerates, the latter in greatest abundance towards the base of the series. The boulders are all well rounded but there has been very little sorting. That the coarse material has not been carried far is shown by the fact that, where the formation rests on quartzite, the boulders consist of that rock, and, where it overlies granite, the most numerous variety of boulder is granite. The sandstones and arkoses are commonly red, but yellowish and grey varieties occur locally. North of the Beaverlodge lakes the series is more massive and better cemented than in the other areas where it is exposed. Cross-bedding is everywhere present, and in several localities ripple-marks, sun-cracks, and clay balls were found throughout it. Interbedded with the series are a number of flows of vesicular and amygdaloidal basalt, and sills and dykes of diabase are also found. Faulting in the series is shown by the presence of well slickensided surfaces. No fossils were found anywhere in the series.

Its age is regarded as late Pre-Cambrian and its origin continental, representing a series of basin deposits.

Intrusive Rocks. The intrusive rocks of the region consist of granite, gabbro, amphibolite, norite, quartz-norite, minette, and diabase. As already stated, the granite covers wide areas and intrudes the Tazin series in every area where the latter outcrops. The gabbro is intrusive as dykes and sills in the Tazin quartzites and as dykes traversing the granite gneiss. The amphibolite intrusions also probably represent altered gabbros. The norite intrusions are post-Athabaskan as are also the dykes and sills of diabase.

Structure.

The gneisses of the region are highly foliated, presenting a well banded structure with a general northeast trend. The rocks of the Tazin series are highly folded and metamorphosed, consisting of quartzites, slates, and schists. They everywhere have a high dip, averaging 45 degrees, and at many places stand vertically. The areas where these rocks are exposed to-day are mere synclinal remnants of a once widespread series. Subsequent to their folding and intrusion by granite batholiths, there followed a long period of erosion. The great unconformity at the base of the Athabaska series shows to what extent this erosion had progressed. Post-Athabaskan deformation is marked by low, open folding and by local evidences of faulting. Several great faults in the Tazin series may be traced by the presence of friction breccias. The faulting took place after the complete metamorphism of the series, for the angular fragments consist of Tazin rocks and are identical in character with those on either side of the autoclastic zones. The fault zones can also be traced into the granites. It is quite possible, therefore, that these zones are to be related to the post-Athabaskan faulting.

Economic Geology.

Iron. At several places the Tazin series contains considerable quantities of hematite and a number of claims have been staked on these deposits. Two types are represented: (1) shear-zones in hematite-bearing quartzite; (2) concentrations by the leaching of silica from the iron formation.

An example of the former type is found northeast of Black bay. In a highly sheared zone the regional quartzite has gone over into a sericite schist. The zone contains considerable quantities of red hematite but the concentration has been insufficient to produce any valuable ore and the deposit itself is very limited.

The second type of deposit is seen in the Beaverlodge syncline. The upper portion of the series, as already described, consists of interbedded hematite and quartzite. The structure consists of a syncline with dips on the limbs up to 70 degrees, and pitching to the southwest at an angle of 30 degrees, disappearing under the lake. The total area of the iron-bearing portion exposed covers only 250 acres. The hematite varies from a hard blue variety to a soft red variety and is highly siliceous, except in local well-leached patches. Evidence of the leaching of silica is seen in the transition of quartzite into hematite with porous rock adjacent to the latter and in the fact that the hematite is found in cavities and along fracture planes where circulation would favour leaching. The high grade variety is in too small quantities to be of economic importance in that region. An analysis of a specimen of hematite from this locality gave the following percentages: iron 66·70; silicon 2·12; phosphorus 0·014; sulphur 0·013.

Other Minerals. A specimen collected from a small quartz vein traversing granite gneiss near Fond du Lac, was found to consist of a mass of subfibrous

materials of which jamesonite is the principal mineral; stibnite and sphalerite were also found to be present with chalcopyrite and arsenopyrite in minor amounts.

SOUTHEASTERN SASKATCHEWAN

(*A. MacLean.*)

The season of 1916 was spent in examining the area extending from the southwestern corner of Manitoba to the Estevan district of Saskatchewan and in investigating the lignite deposits and mines about the latter place. Before beginning the field work proper a week was spent in driving from Treherne, Manitoba, where the outfit was stored from the previous season, to Lyleton, Manitoba, where this season's work was begun. This trip afforded the means for a hasty survey of the geology of the country between the Pembina Mountain sheet, completed last year, and the Estevan sheet, on which work was started this year. During the summer a few days were taken, at the invitation of Mr. N. B. Davis of the Mines Branch, to examine exposures to the west and north of Estevan. For assistance and information accorded by Mr. Davis the writer expresses gratitude. W. R. Quinn of Toronto university gave satisfactory services as assistant from July 15 to September 18.

TOPOGRAPHY.

The obvious topographical features of that part of Saskatchewan to the east of Estevan are due to glacial deposits and post-Glacial erosion. The results of the latter are most prominently expressed in the channels of the Souris and its tributary streams. The Souris is characterized in most of this part of its course by a double valley, and in cases even a third valley has been initiated. These valleys have been cut to a depth of 100 to 120 feet below the prairie level and when the ridge separating the two valleys is removed or reduced to a series of buttes the total width is often upwards of a mile. Near Estevan the tributary streams have cut deep valleys but in the eastern part of the area the smaller creeks have for their channels merely shallow trenches in the boulder clay.

Less prominent as a physiographic feature is the broad and gentle slope extending from the region of Oxbow eastward to the Manitoba boundary and to the valley of the Souris river beyond it. This depression is underlain by glacial debris of varying depth, and is probably the present expression of a pre-Glacial drainage valley, the channel of which was somewhere between the inter-provincial boundary and the valley of the Souris to the east of it.

GENERAL GEOLOGY.

In the stratigraphic series the lowest member recorded anywhere in the field is the upper part of the Odanah shale of the Pierre. This is exposed in the bed of the Souris between Dalny and Coulter, Manitoba, and on the east side of the valley of Blind river near Melita, Manitoba. West of this and nearer the Saskatchewan boundary it is encountered only in drilling operations and is only 100 feet thick. It seems to have the same characteristics as distinguish it in the Pembina Mountain area, but as noted above it is much thinner. Above the Odanah shale a bed is reported by the drillers to occur which is known to them as "soapstone." From the description this is probably a colloidal clay shale. At Sourisford, Manitoba, the bed is said to carry a coal seam a few inches thick.

In the only area where the Odanah and colloidal clay shale are known the latter is succeeded upward by boulder clay so that its immediate chronological successor is unknown. The next known beds of pre-Glacial formation are those of the Estevan region, exposed along the banks of the Souris and its tributaries in that district. These beds are placed in the Fort Union formation[1], and are characterized by clays, sandy clays, sandstones, and silts with lignite beds in the sandy clays. In the lowest natural exposures along Souris river near Estevan the clays are quite colloidal and are devoid of sandy particles. The depth or thickness of these beds is unknown. Above this there are 50 to 60 feet of more sandy clays in which the colloidal tendency is still quite marked. It is in these beds that the lignite seams occur, the uppermost of which is between 1 foot and 3 feet below the top. The sandy colloidal beds are succeeded upward by a yellow, non-colloidal, calcareous clay which might perhaps be better termed a silt. In this some of the bands are consolidated or cemented to form a sandstone of irregularly continuous beds from 3 to 18 inches thick. The surfaces of these sandstone bands are often ripple-marked. In the Estevan district this forms the top of the section, but toward Roche Percée these beds are merged into, or succeeded upward by, a more massive sandstone more nearly consolidated. Along Short creek near the latter place this sandstone contains some remnants of fairly well preserved leaves. Owing to the pronounced lateral variation exhibited in the field it is impossible to give a detailed section which will correctly represent every part of the whole area. In a general way, however, the following divisions may be recognized:

Stratigraphical Section.

	Thickness feet.
Glacial and post-Glacial deposits	—
Silt, or yellow calcareous sandy clays without marked colloidal properties, generally well laminated, sometimes massive. Often contains sandstone bands and calcareous concretions	15+
Light or dark yellowish green, more or less colloidal sandy clays. Some of the bands may be almost devoid of sand and quite colloidal. Carbonaceous material present in gradations from the ordinary darkened clay in which it is disseminated to the peaty layers and lignite seams, from ½ inch to 12 feet thick. The larger lignite seams are grouped in two sets, one near the top and the other near the bottom of this part of the section. On exposures facing in a southerly direction the surface becomes hard and of a dull grey colour	50 to 60
Dark yellowish green or brownish green, colloidal clays with little or no sandy particles	—
Below this (which forms the base of the natural exposures) the only records obtainable are derived from drillers' logs which do not differentiate the character of the clays, but which at 400 feet located seam of lignite of thickness	4
And at 600 feet another seam of lignite of thickness	5

For information concerning these lower seams I am indebted to Mr. Symonds, Mr. Peterson, and Mr. Darling.

Near Estevan two seams of lignite are worked, one belonging to the upper group and one belonging to the lower group. The upper as worked is generally 7 feet thick and the lower 3½ feet thick. The section adjacent to the upper at the Estevan Brick and Coal Company's plant is as follows:

[1] Dowling, D. B., Geol. Surv., Can., Mem. 53, p. 59.

Section at the Estevan Brick and Coal Company's Plant.

	Thickness feet.
Yellow clay or silt	15
Sandy colloidal clay	3
Mixture of clay and lignite	0·3
Main lignite seam	7·4
Clay	0·6
Lignite	0·2
Black clay and sand	0·5
Lignite	1·4
Clay	1·5
Lignite	2·7
Sandy colloidal clays, about	35
Lower group of lignites and clays from	8 to 10.

The thicknesses of the lignite seams and the clay partings vary considerably in different parts of the field and even in different parts of the same quarry or mine. In the above case for instance the measurements given would not be correct for a point 200 feet distant from where these were taken.

In the SW. ¼ of sec. 16, tp. 2, range 8, the section including the lower group of lignite seams is:

	Thickness inches.
Sandy colloidal clays	
Lignite	24
Clay	18
Lignite	8
Clay	16
Lignite	15
Clay	27
Lignite	42

Clay, more colloidal and less sandy than the upper lies below this last lignite.

In this group the 42-inch seam is the only one worked and as in the case of the upper group the thicknesses of the seams and partings vary in different parts of the field. Five miles to the southwest of Estevan, on the farm of Niels Andersen, sec. 28, tp. 1, range 8, the lower group is represented by a seam of lignite 12 to 15 feet thick, with a thin clay parting near the bottom. The upper seam at this place varies less in thickness and arrangement from the type section in the Estevan Brick and Coal Company's yard, described above.

Owing to disturbances resulting from subsidence and other movements near the river valley it is rather difficult to determine with accuracy the attitude of the beds, but all the evidence seems to point to a dip toward the northeast at a rate of about 5 feet per mile.

ECONOMIC GEOLOGY.

The economic geology of the field is concerned with the lignite, the manufacture of brick and tile from the shale and clay, and the possible occurrence of gas.

Lignite.

The lignite mined at Estevan and in the immediate district is in the upper group, the 7-foot seam, for the most part, although a few mines are operating on the 3 or 4-foot seam of the lower group. This latter is a somewhat better fuel probably but is more difficult to mine. The lignite mined at Shand and in the Bienfait district is apparently on a seam not continuous with either of these groups.

In the mining of the lignite there is too often but little attention paid to the conservation and efficient recovery of the fuel. In some cases considerable lignite is left in the floor and roof of the mine and in others the upper seam is destroyed through the lower one being mined first without any concern for the subsequent dislocation of the underlying beds. The amount of lignite destroyed through faulty practice varies from one-third of a ton to 2 tons for every ton recovered. As the amount of fuel is by no means inexhaustible these methods seem altogether too wasteful.

Clay.

From the upper yellow clay there is made a very satisfactory soft-mud brick and hollow tile. The lower clay between the two groups of coal seams is too colloidal to be used in this manner but it is used to produce a dry-press brick of good quality.

Mr. N. B. Davis of the Mines Branch has called to my attention a fireclay white in colour, which is sometimes found above the lignite seam at the top of the colloidal clay group, or perhaps replacing some of the lower layers of the yellow calcareous clays. It has not been found in the immediate vicinity of Estevan, but has been located by Mr. Davis in the neighbourhood of Halbrite and in the Big Muddy district.

Gas.

Gas has been struck in one or two of the deep wells in the neighbourhood of Estevan but the information concerning them is meagre. From such information as is available it appears that there is little change in the character of the clay shale for a depth of 600 feet. If this inference, drawn from the records examined, is correct, then there is small hope of any large amount of gas being found within these limits.

To the east of the Saskatchewan field, in the region along Souris river between Sourisford and Melita, gas has been found only in small quantities. It probably originates in beds below the Millwood of the Pierre through which it escapes to the Odanah shale above. This forms a very satisfactory reservoir, especially as it is capped by the colloidal clay shale previously mentioned and by boulder clay. Unfortunately the channel for its entrance into the Odanah is probably small and the limits of the lower beds from which gas can be drained are narrow. There is, therefore, little hope for the development of an extensive gas field in the region.

SCHIST LAKE AND WEKUSKO LAKE AREAS, NORTHERN MANITOBA.

(*E. L. Bruce.*)

The season of 1916 was spent in continuing the mapping of the Amisk-Athapapuskow Lake area. The western part of the district will be dealt with in a fuller report later and details will be omitted here. At the end of the season, a brief visit was made to the Wekusko (Herb lake) section where there is considerable activity at present, but the freeze-up being somewhat earlier than usual, the time available for work there was much shorter than planned.

To expedite the mapping of the great number of lakes and waterways, the party was divided and work was carried on independently but with frequent conferences to compare results. The geological work of one party was in charge

of Angus McLeod, assisted by F. M. Wolverton. The micrometer surveys to fix the geographic base for this party were made by W. J. Embury. On the other party the writer was assisted in the geological work by L. G. Thompson and in the micrometer work by G. O. Vogan. The work of all these men was entirely satisfactory. Flinflon lake is mapped from a stadia traverse by Mr. F. H. Kitto, D.L.S., and the river below it from a stadia traverse by Mr. C. M. Teasdale, D.L.S.

Every facility and assistance possible was given the party by those working in the area and special thanks are due Mr. H. C. Carlisle, engineer in charge of the Tonopah properties, for his kindness.

Schist Lake Section.

The finding of large bodies of sulphides, reported in the autumn of 1915,[1] stimulated the search for deposits of a similar nature. As a result, soon after the freeze-up a second body was discovered on Schist lake about 3 miles southeast of the original discovery on Flinflon lake. Up to the time of writing these two are the only sulphide bodies that appear to warrant investigation. On both properties diamond drilling was done in the summer of 1916 and on the Schist Lake claims is still in progress. At Flinflon, an immense body of sulphides has been proved but the values are as yet known only to the owners and to the company to which the claims were optioned. The Schist Lake claims are under option to the Tonopah Mining Company and following extensive drilling the possibility of transporting ore by boat and tramway to the Pas is being considered. As this section seems likely, for the present at least, to be the focus of activity, a summary of the geology will be given. A more detailed discussion will be reserved for the report to follow.

MEANS OF ACCESS.

The Schist Lake district is reached most easily from the town of Pas where the Hudson Bay railway crosses Saskatchewan river. From that point, during the summer months, regular steamers ascend the Saskatchewan to Cumberland House and then turn northward across Cumberland lake and Namew (Sturgeon) lake to the mouth of Sturgeon river. Thence the route lies by canoe up Sturgeon river and Goose creek to Goose lake to Athapapuskow and thence to Schist lake. The Manitoba government has cleared a road from Sturgeon lake to Athapapuskow lake, so that the rapids of Sturgeon river and its tributary Goose river are avoided. However, until development warrants the expenditure of considerable money on this road it will be difficult to do much freighting over it in the summer months owing to the big muskeg area between Goose and Athapapuskow lakes. It is unfortunate that the Hudson Bay railway is so far from the promising area as to make the cost of railway connexions almost prohibitive. As a result it seems likely that it may be found possible to ship only high grade ore, discarding a much larger tonnage that with good shipping facilities might be profitably treated.

TOPOGRAPHY.

In this part of its course Saskatchewan river flows through flat, marshy country in a network of changing channels. Flanking the river are many broad, shallow lakes in some places separated from the river channel only by a narrow willow-covered levee. These lakes form equalizing reservoirs into which water

[1] Geol. Surv., Can., Sum. Rept. 1915, pp. 126–130.

flows in flood time to be later fed out again as the water-level of the river falls. Sturgeon lake may be considered as such a reservoir. Normally, the muddy Saskatchewan waters are not found north of Cumberland lake but in high water the Sturgeon Lake water-level rises as much as 5 or 6 feet. Northward from Cumberland lake the country is flat and marshy with few outcrops away from the lake shore. The Silurian-Ordovician boundary line is crossed somewhere between Cumberland lake and Sturgeon lake but is not here marked by any escarpment as it is at other places[1]. The ascent is more rapid northward from Sturgeon lake, the increase in elevation being marked by rapids on the river. Inland, however, it is still imperceptible. The edge of the Ordovician is commonly marked by an escarpment which forms the most noticeable physiographic feature in the district, standing 70 to 80 feet above the hummocky Pre-Cambrian floor. Lake Athapapuskow lies along this escarpment, which bends southward to the north end of Goose lake. In this embayment in the escarpment, which may represent a pre-glacial river channel, is the present outlet of lake Athapapuskow to Goose lake.

Although along the boundary of the two formations the Pre-Cambrian in places lies as much as 80 feet below the surface of the Ordovician, the older formation is much more rugged. The local relief, however, is seldom more than 50 feet. The general trend of the ridges is northwesterly, the larger lakes lying in basins eroded in the softer schistose and slaty rocks between fingers of granite. Usually the granite forms a higher upland between the lakes, but in the vicinity of Schist lake the upland consists of more basic formations. Ross lake, between the north end of the northwest arm of Schist lake and Flinflon lake, lies in a striking basin eroded in a trough of sedimentary rocks pitching northwesterly and probably bounded on the east by a fault zone.

GENERAL GEOLOGY.

The geological relations found in the district are expressed by the following table:

Table of Formations.

	Recent	Peat, river silts.
	Glacial	Sand, till.
Palæozoic	Ordovician	Dolomite.
	Unconformity	
Pre-Cambrian	Granite.	
	Granite gneiss.	
	Intrusive contact	
	Conglomerate and arkose.	
	Unconformity (?)	
	Slate	
	Unconformity	
	Altered volcanics (greenstone, greenstone schists, etc.), diorites.	

Structurally, the country consists of closely compressed folds with their axes striking northwest-southeast and pitching northwesterly. Along the axes of these folds, granite intrusions have found their way. There has also been

[1] Kindle, E. M., "Notes on the geology and palæontology of the Lower Saskatchewan River valley", Geol. Surv., Can., Mus. Bull. No. 21, p. 2.

much faulting, paralleling in a general way the trend of the axes of the folds, and along these fault zones granite tongues have been intruded. Deep erosion has now exposed these granite intrusions, leaving them as the divides between the waterways which have to a considerable extent adjusted themselves to the zones of softer rocks. Extreme deformation and alteration of the oldest rock group make the interpretation of its structure very difficult. In places the interbanding of schistose and massive rocks is so definite that it seems to be due to original differences in composition rather than the result of purely dynamic conditions, and detailed work on these areas might result in unravelling the structure of even this contorted basal complex.

Lithologically, the basal complex consists of various types but as these are, as is usually the case in volcanic rocks, very inconstant in character it has not been attempted to differentiate them in mapping. The most widely developed variety is a surface flow of medium character now altered to a massive, dark green chlorite rock. This commonly retains the typical pillow structure of basic surface rocks and also, not rarely, amygdules filled with calcite and other secondary minerals. Pyroclastic rocks are found as a less usual type where the bombs of lava were thrown from the craters of the old volcanoes and were included in the still molten lava flows or in the ash beds. Autoclastics were formed by the rolling and brecciation of the flow and recementation of the broken and cracked material. Both these types may now appear very much like real conglomerates. Many areas of much altered, basic rocks, which are probably intrusive, are included with these surface types. They were probably originally dioritic or gabbroic in nature.

The slate listed as unconformably above the volcanic series has not been proved to be so. This relation is inferred, since in the Amisk Lake section slate of similar character is separated from the greenstone series by a thin conglomerate layer carrying greenstone fragments. The slate is a soft, black, fissile rock that in places is silicified and harder, and in such places is very similar to parts of the greenstone. It weathers to a rough surface showing $\frac{1}{8}$-inch bands greyish and brownish grey in colour.

The series next above the slate is undoubtedly unconformable on the greenstone group, but, as the conglomerate and arkose are not in contact with the slate, the relation to it is assumed from the similarity of these rocks to rocks in the district to the west. The supposedly younger series consists of a thick conglomerate carrying many pebbles of greenstone, jasper, quartz, and porphyry, which are often squeezed, broken, elongated, and twisted. The matrix, originally a coarse sandy material, is now altered to a felt of white mica, quartz, and feldspar. Where pebbles are lacking this passes into arkose which in the field is hard to distinguish from a mashed granite. The coarse conglomeratic and finer arkosic layers pass into one another along the strike. This irregularity of character is such as would be expected if the original sediments were deposited in rapid streams. The character of the material seems to show that there must have been a great granitic area somewhere in the neighbourhood in this early time as the great mass of quartz, feldspar, and minerals from the alteration of feldspar could not have been derived from the debris of the greenstone group alone. At Amisk lake there are many dykes of quartz porphyry older than the group of sediments. It is possible that these may have been feeders to a great flow of quartz porphyry lavas earlier than the conglomerate and from which it derived much of its material.

As previously mentioned, this group of rocks usually weathers into basins. One of these is strikingly developed at the north end of the northwest arm of Schist lake. In it lies Cliff lake, Ross lake, and the streams draining them to Schist lake. From the high greenstone ridges north of the Tonopah claims, the southern part of this basin or trough can be well seen where the forest

fires have left the rocks bare. The greenstone forms the rim of the trough beneath which the sedimentary rocks form a well-marked terrace. On the western and southern sides the beds dip steeply away from the enclosing greenstone. On the eastern side the two rocks are separated by a marked drift-filled valley which probably represents a fault zone. The folding which has produced this pitching syncline has been so intense that along the base of the younger rocks there has been considerable movement parallel to the bedding, which has granulated the basal beds.

Intruding this series are granites which, although varying somewhat in appearance, probably represent merely variations in the same great intrusion. The introduction of this molten material and its solidification no doubt occupied a great length of time; the earlier injected part of it may be represented by the faintly gneissoid granite outcropping to the west of Flinflon lake and the massive, pink granite of Phantom lake may be the representative of the later stages. Excepting this faint gneissic banding the two are quite similar in character. There is also a greenish granite that is very commonly found intruded along shear zones. In nearly every such instance there are sulphide lenses along these contacts. Some of these dyke-like masses of granite are shown on the map, but there are a great many smaller ones in the district between Flinflon and Big Island lakes which have not been outlined.

The Ordovician is represented by nearly flat-lying dolomite separated by a great unconformity from the preceding formation; but as this has no connexion with the ore deposits a description of it will be omitted here. The glacial and recent deposits in this particular section are not at all important and a large part of the promising rock formations is well exposed.

ECONOMIC GEOLOGY.

The type of deposit that has created interest in this section consists of lenses of almost solid mixed sulphides. The two discoveries made late in the autumn of 1915 still are the only ones that seem to merit development.

Flinflon Lake.

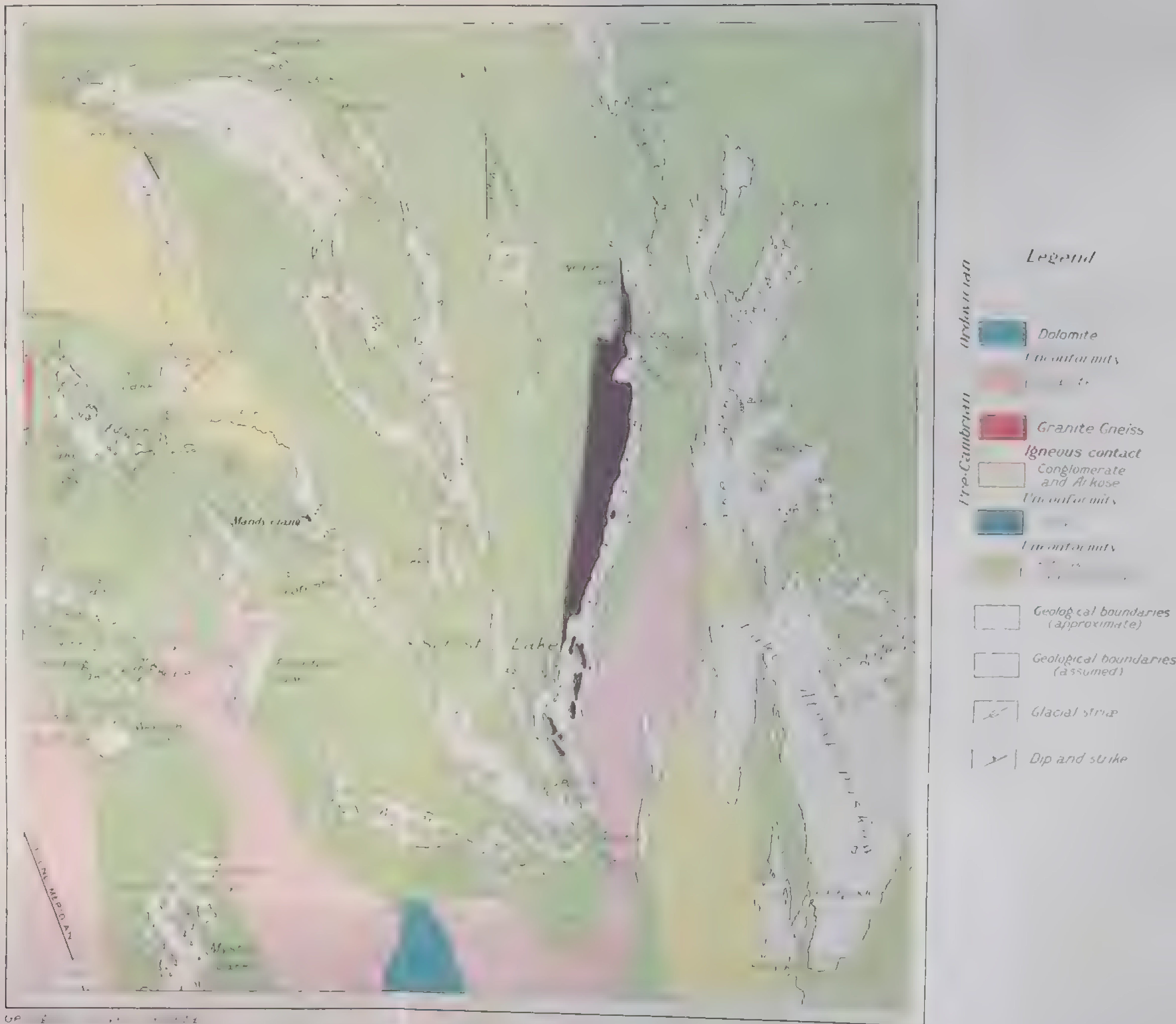
At the Flinflon Lake deposit there has been no surface work since the trenching done immediately after its location. From March to July, 1916, two diamond drills were working steadily on this property and it is understood that they proved the existence of a great body of sulphides. The values have, of course, not been made public. A series of trenches across the strike of the ore zone on the north side of the broad point upon which the ore outcrops shows 55 feet of sulphides, 40 feet of barren rock, and then 30 feet more of sulphides. The sulphide band is unbroken 400 feet south of these trenches and is 75 feet in surface width. Some disseminated ore is found on the borders of the main mass of ore. Ore has again been found 800 feet to the north of the main trenches, but at that place the lens is much narrower. Assuming that the ore found in the northerly trench belongs to the same lens as that in the south exposure, the deposit is more than 1,200 feet in length. No doubt the deposit will be found to consist of not one simple lens but several lenses. The dip of the zone is 60 degrees to 70 degrees to the northeast. The country rock is an altered lava which shows pillow structures in many places. A short distance west of the ore zone and parallel to it, there is a lamprophyre dyke and a small dyke of dioritic or gabbroic character is found a short distance east of the ore zone. North of the main workings a small dyke of granite porphyry forms the hanging-wall for a short distance. With these exceptions the wall rock is a fairly uniform greenstone. The sulphides

are deposited in a great shear zone following the general direction of the fracturing northwest-southeast. Along the fault zone mixed sulphides have been deposited, but with a predominance of certain minerals along certain zones giving the ore a banded character. This has the appearance of being an original structure and is not due to any secondary fracturing of original sulphides with a later infiltration of sulphides of different character. The banding of the ore may be due to a sort of selective precipitation due to original differences in the replaced material, or to a difference in the size of grain in the ground-up rock of the fault zone. The sulphides are massive with some mineralized or slightly mineralized country rock. The most abundant mineral is pyrite which is almost unmixed along the foot-wall side. Towards the centre of the zone, some sphalerite (zinc sulphide) occurs and still farther towards the hanging-wall chalcopyrite is found. Galena is present sparingly. In all of these there are some values in gold and a little silver.

Schist Lake.

The deposit on Schist lake being worked by the Tonapah Mining Company, is on a hook-shaped point on the northwest arm of the lake. It lies about 3 miles southeast of the Flinflon claims, but in such heterogeneous rocks as these it is very unlikely that one is the continuation along the strike of the other. It is smaller than the Flinflon deposit and lying somewhat higher above lake-level it has been possible to outline it more thoroughly by trenching. Diamond drilling has also been resorted to and the company now has fairly complete information as to the size and value of this lens. A detailed discussion of the structure of this body will not be undertaken here. It will be sufficient to say that from present developments it differs from the Flinflon body in apparently being explainable as a drag fold due to the same folding that produced the northwest pitching syncline of sediments just north of it. The drag folding (no doubt aided by considerable shearing) opened up the passages for the ore solutions given off by the neighbouring granite intrusions.

The rock in which the lens lies is interbanded, massive greenstone and soft, green, fissile, chlorite schist in zones of about 50 feet in width. The dip is steep to the eastward, the strike parallel to the lake shore. The contact between the schist and the massive rock is sharp and well defined. The ore lens lies in a schistose zone and drilling has shown that mineralization is almost entirely lacking in the massive rock. The body of sulphides is elliptical in plan with two tongues of sulphides $1\frac{1}{2}$ to 2 feet wide running off from the northwest and southeast sides parallel to the strike of the enclosing schists. At the north end the ore pitches beneath barren rock and a vertical shear zone, with a strike parallel to the axes of the ore-body, continues northward from this point. The drills have shown that the lens does not continue far northward beyond the place where it pitches beneath the surface. The length of the lens on the ground is 225 feet, the width at the middle 40 feet. The mineralization is similar in character to that at Flinflon but the relative proportions are different, the various sulphides being less intimately mixed and the lens as a whole carrying a higher percentage of chalcopyrite. The foot-wall of the zone, which dips to the eastward at an angle of 75 degrees, consists of 10 to 12 feet of almost unmixed pyrite. Lying east of this is a 12-foot lens of high grade chalcopyrite, which does not run from end to end but tapers out before reaching either the north or south extremity. At the south end the pyrite wraps around it and at the north end sphalerite has a similar relation. The sphalerite fills the whole north end of the lens and with some admixture of chalcopyrite forms to the east of the chalcopyrite zone a band 10 to 15 feet in width. The hanging-wall side is pyrite. The northwest stringer is mostly pyrite, while the southeast one consists mostly of chalcopyrite. The sulphides



Schist Lake district, Manitoba

Scale of Miles

To accompany Summary Report by E L Bruce, 1916

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Diagram showing magnesite deposits
Lot 15, range XI, Grenville township, Argenteuil county, Quebec

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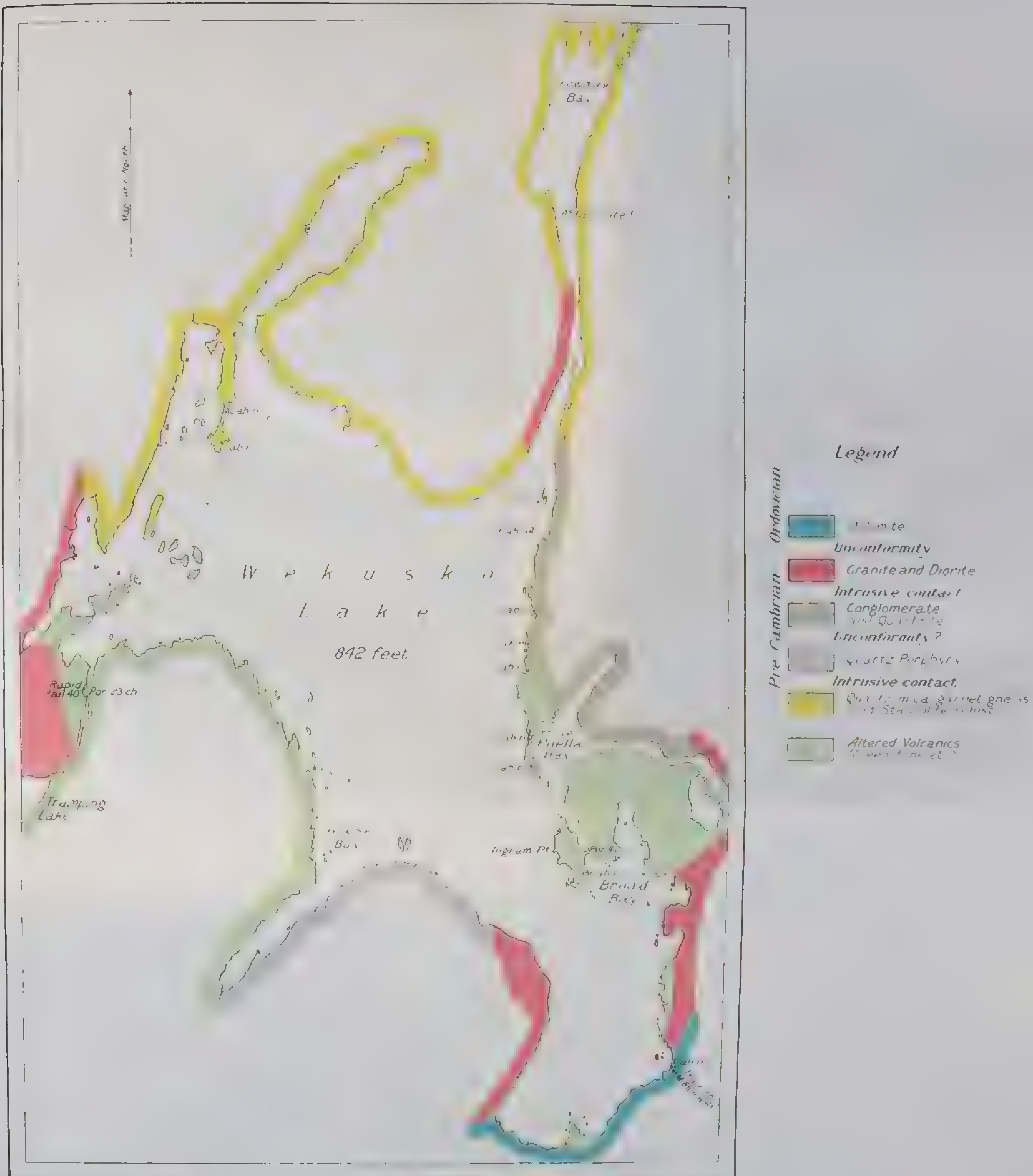

Geological Survey, Canada

Wekusko lake, Manitoba.

Scale of Miles

To accompany Summary Report by E.L.Bruce, 1916

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carry low values in gold and silver. Assays of samples from the chalcopyrite bands and sphalerite bands taken from the middle of the ore zone, give the following results:

Assays of Ore from Tonopah Property.

	Gold, oz. per ton.	Silver, oz. per ton.	Copper %	Zinc %
Chalcopyrite.........	0·04	0·12	28·96	......
Zinc blende..........	Trace	1·52	......	46·60

Assayer, H. A. Leverin.

Thus the chalcopyrite sample is nearly 85 per cent chalcopyrite, the blende sample 75 per cent sphalerite. These are picked samples but are sufficiently representative to show that the chalcopyrite lens in the middle of the ore zone will produce high grade copper ore and that the zinc is in important amount. From these assays the silver is seen to be, as is ordinarily the case, higher in the zinc blende than in the other sulphides. Secondary copper minerals are found in small quantities, the presence of the ore being first detected by a slight stain of copper carbonates along the lake shore. In some of the open fissures in the ore crusts of chalcanthite (copper sulphate) have been found. Underneath the clay pockets of a light porous white mineral are found. This is the variety of opal, called floatstone.

In massive greenstone close to the eastern margin of the trough of conglomerate in which Ross lake lies, some bodies of pyrrhotite have been found. These carry only small quantities of nickel, too small to be valuable. Outside of this section, chiefly in the country north of Elbow lake, other pyrrhotite bodies have been found, but these also carry too little nickel to be economic possibilities.

Future of the Sulphide Deposits.

From the descriptions just given it is seen that there are here sulphide ores which give promise of becoming producing properties. It is at least certain that some parts of the lenses already located are sufficiently high grade to be mined and shipped even under present conditions. Unfortunately, the amount of this rich ore at present proved is not very large. The distance from railway connexions makes the handling of low grade ore an impossibility and unless the lower grade sulphides are found to be sufficiently rich to bear the added expense of at least 75 miles of railway construction only the exceptionally rich chalcopyrite and possibly the zinciferous ore will be mined. The gold and silver values in the ore are not sufficiently high to make the sulphide bodies valuable as sources of the precious metals alone. To make such bodies workable, the presence of enough chalcopyrite or zinc blende to form a copper or zinc ore is necessary. The gold and silver in such deposits will usually be merely a by-product. Hence in prospecting, it should be borne in mind that the discovery of any variety of sulphides is not sufficient to constitute a commercially valuable property. To be of value, a sulphide deposit must carry a workable amount of chalcopyrite or zinc blende, or some other base metal, and with present means of transportation the percentage of these must be exceptionally large.

Although the sulphides are directly connected with the granitic intrusions, the place most promising for prospecting for sulphides ores is not along the main

contacts between the large masses of granite and the older rocks. At these contacts the temperature at the time of intrusion was probably higher than that at which masses of sulphide usually form. In the old lavas along the offshoots from the main granite mass, near the smaller granitic masses, or at some little distance from the main granite masses, lower temperature and probably some differentiation of the intrusive rock provide the conditions necessary for the separation of the sulphides; and these contacts are the ones that offer the greatest promise of sulphide ores of commercial grade.

Wekusko (Herb Lake) Section.

The gold-bearing veins on the east shore of Wekusko lake were described in the Summary Report, 1915. Some new discoveries in that section and the actual development being undertaken on some of the properties make a further description of this type of deposit desirable. Prospecting here has been for gold-quartz veins, since sulphides are only sparingly present and the mineralization is similar to that in the veins at Amisk lake on the western border of the area.[1]

Wekusko lake is reached by way of the Hudson Bay railway from the Pas. From mileage 86, a trail leads northwesterly to the south end of the lake. This trail is about 14 miles in length and in winter is fairly good. In summer, however, a big muskeg lying between the railway and the lake makes it very wet, excepting in the very dry season. It will require considerable money and labour to make this a passable summer trail. The lake may also be reached by canoe, leaving the railway at Kiski lake and paddling up to Setting lake, or by leaving the railway at mileage 137 and portaging to Setting lake. From Setting lake the Grass river forms an easy canoe route to Wekusko lake, but this route requires two and one-half or three days.

TOPOGRAPHY.

The topography of the vicinity of Wekusko lake is somewhat similar to that of the Schist Lake area, but here the irregular character of the Pre-Cambrian basement is masked and softened by a thick covering of fine greyish clays of glacial origin. As a result, rock outcrops are not common and the country in many places is covered by swamp and muskeg.

GENERAL GEOLOGY.

The geological work in the district has been of the most hurried nature and the present classification must be considered as only preliminary. The following table expresses the relations as at present determined:

Table of Formations.

	Recent	Peat.
	Glacial	Grey clays. Till.
Palæozoic	Ordovician	Dolomite.
	Great unconformity	
Pre-Cambrian		Granite and more basic intrusives.
	Intrusive contact	
		Conglomerate and sheared quartzites.
	Unconformity	
		Quartz porphyry.
	Intrusive contact	
		Quartz-mica-garnet gneisses (sedimentary) and staurolite schist. Altered basic lavas (greenstone and schist).

[1] Geol. Surv., Can., Sum. Rept., 1914, p. 68.

The altered lavas are entirely similar to those from other parts of this area, as described above, and in fact to those of many other Pre-Cambrian areas. They are soft, massive, dark green rocks commonly showing ellipsoidal or amygdaloidal structure. Microscopically, they are found to consist of secondary minerals, mostly chlorite, sericite, uralite, and carbonates. In places, these massive forms are altered to schistose rocks which may represent only local alteration by dynamic processes, or possibly some variation in original composition in the lava itself or the interbanding of clayey material.

The relation of the altered lavas to the heterogeneous sedimentary series made up of quartz-biotite, garnet gneisses, and staurolitic schists, has not yet been determined. No conglomerate that could be certainly interpreted as the basal member of this series has been found. Wherever the lavas and gneisses are close together, one seems to pass into the other. The lack of bedding in the volcanic rock and its obliteration in the sediments makes the interpretation of the succession very difficult. The gneiss is a rusty-weathering, granular rock consisting chiefly of quartz and biotite but with garnets developed plentifully in some localities. The following analysis of this gneiss, together with the peculiar mineral composition and the appearance of the rock, as a whole, imply a sedimentary character:

Analysis of Gneiss.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO
63·84	20·34	3·34	3·98	2·20	0·64
Na_2O	K_2O	$H_2O\mp$	TiO_2	Total	
0·95	2·42	1·05	0·80	99·56	

Analyst, M. F. Connor.

East of the area under consideration, this gneiss gives place to a conspicuously banded black and white gneiss that weathers black and red. The white layers have a pegmatitic character and it is believed that this rock is a hybrid formed by the injection of granite or granitic vapours along the foliation of the quartz-mica gneiss or of the staurolitic schist. This is rendered the more probable since there are many small areas of granitic rocks in this gneissic area.

The staurolite schist is found only in narrow bands. A prominent outcrop occurs on an island in Crow Duck bay, another is found on the northwest shore of the lake, and a third crosses Grass river below lake Wekusko. The staurolites form a conspicuous and in some places an abundant constituent of this rock, which was probably originally a clayey sediment.

Quartz porphyry forms the surface rock of an area lying southwest of lake Wekusko. It is a dark, coarsely porphyritic rock intrusive into the greenstone but, so far, not recognized in contact with the sedimentary gneiss and staurolite schist.

On the east side of the lake, there are conglomerates which contain pebbles of greenstone, quartz, and jasper. Along with them are very badly sheared acidic rocks, that in the hand specimen have the appearance of porphyries, but, from microscopic evidence, they might be sheared quartzites. Their field relations are somewhat contradictory. McLeod found an exposure where rock of this class had the appearance of intruding the old lavas, while on the Elizabeth claims there seems to be an interbanding with typical conglomerate. It is possible that we have here both a quartzite and a quartz porphyry from which the intense shearing has produced very similar schistose rocks. For the purpose of this report the conglomerate and the sheared acidic rock will be mapped together as conglomerate and quartzite.

Intrusive into all these types are varieties of granitic and dioritic rocks that probably represent merely various contact and differentiation facies of the one

mass. Northwest of Wekusko lake, the intrusive is a very fresh, bright red granite; southwest of the lake, it is very dark coloured but may possibly be similar to the other mass at a greater distance from the contact with the greenstone than it has yet been seen; east of the lake are other masses of dark-coloured, dioritic intrusives to which the same statement applies; and on the big point at the north end of the lake is a mass of very coarse-grained diorite porphyry, many specimens having phenocrysts of feldspar an inch in length.

This lake forms one of the long string of lakes lying along the escarpment of the basal Palæozoic rocks. Here, the flat-lying Ordovician dolomites form cliffs 60 to 70 feet above the south end of the lake. They are very similar to the dolomites already described. They rest with a great unconformity upon the Pre-Cambrian rocks but without any basal conglomerate. The two have not been found actually together but the dolomite only a few feet above the base is fairly pure and carries chert concretions. There have been found no fragments of any conglomerate which could be interpreted as the normal basal member of this series. This rock, separated by an enormous length of time from the rocks upon which it rests, has no association with the ores of the district.

Covering the solid formations is a thick mantle of greyish to brownish clay without pebbles, which makes thorough prospecting a very laborious undertaking. There is but little true boulder clay. In the valleys and the broad muskegs away from the well-drained areas along the waterways, there is a considerable thickness of peat above the clay.

ECONOMIC GEOLOGY.

During the summer of 1916 there has been considerable prospecting and development of the claims grouped along the eastern side of Wekusko lake. This has resulted in the discovery of some new veins; one group of claims is now under option and it seems likely that this section will now be thoroughly tested. A shaft is being sunk on a vein on the Moosehorn claim. This vein is small, varying from 8 inches to $1\frac{1}{2}$ feet in width, but the gold values are exceptionally high. In a sample given to the writer by Mr. Robert Kerr, some of the particles of gold were surrounded by a soft steel grey, metallic mineral which, on examination by R. A. Johnston and E. Poitevin, proved to be a telluride of gold, probably petzite. Platinum has also been reported from this vein but tests failed to show it, and the presence of platinum in such association would be a most unusual occurrence.

The veins occur in the altered basic lavas, in the sheared quartzite and conglomerate, and in the sedimentary gneisses. Some have, in places, as great a width as 8 to 10 feet; but as in most veins of Pre-Cambrian age, they are lenticular. In general in the larger veins, though gold is visible in many places, the values are very inconstant and only a mill run will give a fair idea of the average gold content. In the smaller veins, such as that on the Moosehorn, the values are more evenly distributed and much higher. Besides gold, the mineralization consists of small amounts of arsenopyrite, usually along the walls, and a very little chalcopyrite and pyrite scattered through the quartz. The non-metallic minerals are tourmaline in needles and in masses, and quartz.

As shown by the presence of tourmaline and tellurides, the veins are very evidently high temperature deposits. They have been formed at great depths and the part now at the surface has been exposed by the removal of great thicknesses of rock since the time of the introduction of the vein material. They are no doubt connected with the intrusion of the granitic masses from which they have also derived their content of gold. But as they were formed at great depth and, therefore, under high temperature conditions, it does not necessarily follow

that only the area close to the granite will be found to have gold-bearing veins. Also the depth of the granite beneath any part of the older series is not known and is probably not very great, and so it may be expected that veins are possible in any of the formations preceding the granitic intrusion. They will, however, be influenced by the character of the rock; fairly massive and brittle rocks are more likely to bear well-defined veins than softer schistose and yielding rocks, such as the staurolite schist. If veins were found in the latter type, they would very likely be of irregular, lenticular, and discontinuous character. Also the character of the rock may be expected to have had some influence on the amount of gold precipitated in the vein.

The termination of the extension of time for performance of assessment work will no doubt force the prospecting of many claims that have up to now had no work done on them and there seems to be promise of the discovery of more veins similar to those already uncovered. This section should be a rather attractive area for prospecting during the next season.

GOLD-BEARING DISTRICT OF SOUTHEASTERN MANITOBA.

(*J. A. Dresser.*)

That part of the province of Manitoba which lies between the southern part of lake Winnipeg and the eastern boundary of the province is scarcely 50 miles in width. It lies between 51 and 52 degrees north latitude, and between 90 and 91 degrees west longitude. In sharp contrast with the deep soil and more recent geological formations of the prairie portion of the province, this district bears very little soil and over large areas rocks of early Pre-Cambrian age are widely exposed. The discovery of gold in these rocks has attracted considerable attention to the district in recent years and it is confidently hoped that important economic development will ensue. The following report gives the results of a reconnaissance of a few weeks in the district during the summer of 1916. The object of the reconnaissance was to get a general view of the economic possibilities of the district.

PREVIOUS WORK.

In 1891 a reconnaissance covering the east shore of lake Winnipeg and valleys of the principal tributaries was made by J. B. Tyrrell assisted, in the northern part of the region, by D. B. Dowling. Mr. Tyrrell published a summary of the general geology of the southern area in the annual Summary Report of the Geological Survey for that year, and a report on the entire district was afterwards published by Mr. Dowling in the Annual Report of the Geological Survey, vol. XI, 1898.

In 1912 a preliminary examination of the part of the district then known to be gold-bearing was made by E. S. Moore assisted by R. C. Wallace. The results of this examination were published in the Summary Report of the Geological Survey for 1912. Besides the above, articles descriptive of the district have been published by R. C. Wallace and J. S. Delury in the Canadian Mining Journal, Toronto, the Mining Magazine, London, and in other journals.

LOCATION AND ACCESS.

The district within which gold has thus far been discovered is some 10 by 50 miles in extent and is situated in the narrow part of the province of Manitoba

lying between the southern part of lake Winnipeg and the province of Ontario. Several small rivers cross the region in a northwesterly direction, having their sources near the Ontario boundary and emptying into lake Winnipeg.

The gold-bearing areas, as far as known, occur within the watersheds of two of these, the Manigotagan (Bad Throat) and the Wanipigow (Hole). These rivers are about 6 miles apart, and run approximately parallel. They enter lake Winnipeg about 70 and 75 miles north of the southern end, or head of the lake.

In summer the mouths of the rivers may be reached by steamer from Selkirk, on the Red river, 21 miles south of its entrance to lake Winnipeg. Selkirk is connected with Winnipeg, 22 miles distant, by the Winnipeg and Lake Winnipeg electric railway and by the Canadian Pacific railway. Two transportation companies operate boats on lake Winnipeg during the season of navigation, the Northwestern Navigation Company and the Northern Fish Company, both having offices in Selkirk. From the mouths of Manigotagan or Wanipigow rivers the district is reached by a canoe trip of 35 to 50 miles according to the part of the district it is desired to reach. When a choice is possible, the Manigotagan is the preferable route. Small canoes should be used, unless for freighting on the Manigotagan, as many of the waterways are small and are obstructed by brushes and fallen trees.

In winter the usual route is by the Canadian Pacific railway to Riverton, on the west side of lake Winnipeg, thence across the lake to Manigotagan settlement at the mouth of the river of the same name and inland by a winter trail. The construction of a summer wagon road to reach the district from the settlements near the south end of lake Winnipeg is under consideration, but as yet none exists.

Numerous creeks enter the Manigotagan from both the north and the south, and might be made into useful canoe routes for use in prospecting and carrying supplies. At present they are obstructed by brushes and fallen trees but they could be cleared out at small cost, by concerted effort of adjacent claim holders.

SURFACE FEATURES.

The district is one of low relief. A hill rising 100 feet above the surrounding country would be a prominent landmark, but such are rarely to be found. In the lower 50 miles of the Manigotagan river there are thirty rapids which can be passed only by portaging. Eight of these falls or chutes have each a vertical fall of 12 to 30 feet; one, which I did not see, is said to be higher, and the remainder are of less importance. There are, therefore, no water-powers of more than very local use in the district. The total fall between lake Manigotagan and lake Winnipeg, about 45 miles, may be roughly estimated at 250 feet.

The surface of the region has been heavily glaciated, the direction of ice movement being very uniformly south 50 degrees west (magnetic). Comparatively little transported soil or glacial debris has been deposited; forest fires have removed the greater part of the original forest and the growth of young timber is very scanty. Yet, in swamps and in places along the shores of the rivers and lakes there is sufficient timber for mining purposes and wood for fuel can be readily obtained. Large areas, however, are practically free from soil, or timber, and are well exposed for prospecting.

GEOLOGY.

General.

The region on the east of lake Winnipeg is occupied by rocks of Pre-Cambrian age which extend northeasterly to the James Bay depression. On the west of the lake, the country is underlain by Palæozoic strata which form an ascending

series to the westward. The district is thus a part of the extreme southwestern border of the great Pre-Cambrian "shield"—the area that has already produced the major part of the mineral wealth of eastern Canada.

Local.

In the district examined there are three geological formations besides the surface deposits. These are a series of porphyries, andesites, and greenstones, probably extrusive in origin; a group of quartz biotite and other schists and gneisses, largely, if not wholly sedimentary; and numerous bodies of granite, pegmatite, and gneiss intrusive into both of the preceding formations. It is not yet clear which of the first two formations is the older. They were not seen in actual contact and both are older than the granite. Their different origin, however, suggests that there is probably a difference in age. Tyrrell[1] treated them together as forming an older series distinct from the later granite gneiss. Moore[2] on the other hand considered the sediments which he named Wanipigow to be younger than the porphyries and andesites (Rice Lake series) mainly from evidence obtained in adjacent parts of the region, where a conglomerate was found which was not seen during last summer's exploration in the Clearwater-Long Lake district lying northeast of Manigotagan lake. As it was not a matter of immediate economic importance the age relations of these two formations were not further studied.

In tabular form the formations may be provisionally arranged as follows:

Table of Formations.

Quaternary	Pleistocene	Lake deposits. Glacial drift.
	Unconformity	
Pre-Cambrian	Manigotagan granite, pegmatite, and gneiss.	
	Intrusive contact	
	Wanipigow series: mica schists and gneisses. Rice Lake series: porphyry, andesite, and greenstone.	

Description of Formations.

Rice Lake Series. This series is well exposed between Clearwater and Rice lakes, and was seen at many points eastward as far as the east end of Long lake. There is considerable variation in the character of the rocks in different places. For example, on the trail from Clearwater lake to the Moose mine granite porphyry outcrops near the east end of the lake and granite (Manigotagan) at chainage 30, the intervening stretch being drift covered; continuing, porphyry is exposed as far as chainage 65 where the rock becomes fine in texture and passes gradually into a fine andesite which continues to the Moose mine, a total distance of $2\frac{3}{4}$ miles from the lake shore. In a small boss at chainage 86, and in less amount elsewhere the rock is a quite massive greenstone whose original composition must have been extremely basic. It is now a mass of chlorite and epidote containing scattered crystals of plagioclase feldspar. These greenstone masses appear to be only basic parts of the main mass, though there has been so much metamorphism of all the rocks that they may (though not likely) be deformed intrusions.

[1] Op. cit.
[2] Op. cit.

Lithologically the rocks of this series are chiefly feldspar porphyry, quartz porphyry, andesite, and greenstone. All are finely foliated, and over large areas have a singularly uniform dip of 70 degrees towards the south-southwest.

Wanipigow Series. The rocks of this series are exposed on Manigotagan river near Manigotagan post-office and at Woods falls. Rocks intruded by granite at Poplar rapids may also be altered phases of these rocks; if so, the series has a breadth of nearly 3 miles in this vicinity. Upstream nearly to Perry Davis rapids a granite batholith, about 15 miles in breadth, is exposed. Wanipigow schists again appear near Perry Davis rapids and are the principal rock exposed along the Manigotagan for 4 miles. After an interval of 6 or 7 miles underlain by granite and occasional patches of schists, the latter again becomes the principal rock from the outlet of Turtle lake to the west end of Clearwater lake. East of Clearwater, Caribou lake and Manigotagan river appear to mark the general line of a sinuous contact between the Wanipigow series and the Manigotagan granite.

Lithologically the Wanipigow in the area described consists chiefly of a quartz-feldspar schist or gneiss containing much biotite and a little sericite. Light-coloured garnets are found in it, and near intrusions of pegmatite tourmaline is common. It ranges in colour from light to dark grey, but no phases that could be called conglomerate were found. It is a foliated arkose or greywacke.

Manigotagan Granite. This formation occurs in large masses as well as in innumerable dykes and small bosses which penetrate the older rocks. It evidently forms the principal rock south of Manigotagan river for a great part of its length. On the north, too, it forms a large batholith on the lower part of the river and also large masses, that are probably separate from one another, north of Gold lake and of Long lake.

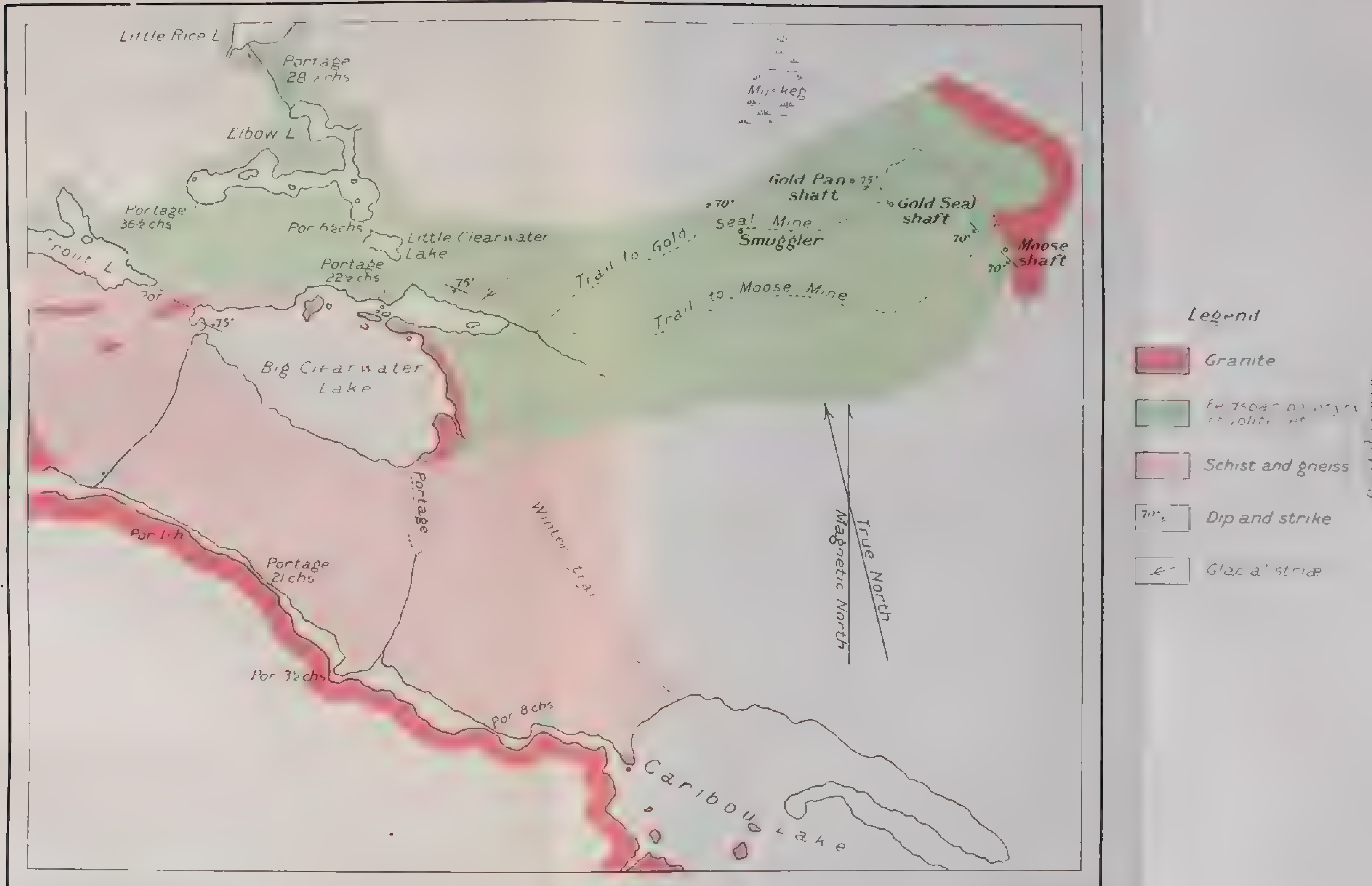
The granite is generally of medium texture, grey or flesh coloured, and is in places gneissic. In places pegmatite veins and masses are large and numerous. Besides orthoclase and quartz there is a considerable proportion of plagioclase feldspar, with lesser amounts of hornblende and biotite.

ECONOMIC GEOLOGY.

Gold.

Mode of Occurrence. The gold thus far found is principally in quartz veins and stringers in shear zones. The country rock of the vein is chiefly andesite or porphyry. In one locality gold occurs in a stringer of quartz in granite at a distance of at least a quarter of a mile from the contact of the granite mass with the older rocks. In another instance sericite schists were found to be mineralized by gold and a little pyrite near a contact with granite. The greater number of the veins seen, however, are in a phase of the porphyry and near the contact with granite.

The gold-bearing veins generally appear to be portions of shear zones, usually under 10 feet in width, which are partially replaced by quartz. Parts of the quartz have a bluish colour, but the larger bodies are milky white. While veins are numerous in the district they average probably less than 2 feet in width of actual vein material. They are variable in individual width according to the proportion of the shear zone that is replaced. A small amount of pyrite and a very little chalcopyrite are commonly present, but the total amount of mineralization is small. A noticeable amount of gossan was observed on only one of the larger veins. An assay of a carefully selected sample of this vein gave only a trace of gold. Prospectors in the district hold the general view that gold is present in proportion to the amount of chalcopyrite, not of pyrite, that occurs in the vein. There is no evidence to the contrary on this point.



Geological Survey, Canada

Catalogue No 1672

Diagram showing gold-bearing deposits in the vicinity of Big Clearwater lake, Manitoba

Scale of Miles

To accompany Summary Report by J. A. Dresser, 1916

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The quartz of certain veins shows distinct evidence of both fracturing and shearing since deposition. The direction of movement in the cases observed was found to be nearly or quite parallel to the walls of the vein. All veins in which this later fracturing was found are gold-bearing. One vein in which no trace of later fracturing was found is as far as known barren. This suggests that gold was deposited only after the vein matter had been fractured and consequently that gold is to be found only in such of the veins as have been so fractured. But further evidence is, of course, necessary to prove that this is always true.

In one place the schistose porphyry was found to be gold-bearing. This is near a contact with granite, where the porphyry instead of finding relief from pressure along a narrow, but well-defined shear zone, as is found in many places in the district near intrusions of granite, has become more or less schistose over a greater width. There are, too, many small stringers of quartz in the schist, at this place, but they are not in sufficient quantity to approach the character of a vein. It was not definitely ascertained whether or not gold actually occurs in the porphyry or is confined to the small quartz stringers. But the total value carried by the sample was greater than would be expected from the relatively small amount of quartz in the sample.

Distribution of Values. Thus far prospecting has centred about four localities, viz., Rice lake, Gold lake, and Long lake, all lying between Wanipigow and Manigotagan rivers, and near Hay lake a short distance north of Wanipigow river. Of one hundred and twenty-four samples taken from all parts of the district, though by far the greater number were from the Gold Lake and Long Lake localities, there were less than 10 per cent that did not carry values above a trace. Therefore, gold seems to be widely distributed in the district; and this is more noteworthy as the total amount of actual prospecting and development of prospects is as yet altogether insufficient to show the value of the camp at all conclusively. Little information is available as to the length of ore chutes. Shear zones, and in places veins, persist for favourable lengths, but little seems to be known of the extent of the mineralization and consequently the possible supply of ore. The shearing of the veins augurs well for their continuance in depth but the values have not yet been proven far below the water level.

Samples were taken from veins varying from 5 inches to 10 feet wide. In these the values seem to be higher in the smaller veins. Thus the average value obtained from ninety-seven channel samples was $7 per ton, distributed as follows:

From veins	5 inches to	12 inches,	average value of	33 samples	$10.55.
"	" 13	" " 36	" "	" " 45	" 5.97
"	" 37	" " 120	" "	" " 19	" 4.10

These figures, however, must be regarded as suggestive of this tendency, rather than as representative of all the actual occurrences that have yet been found. On the other hand the widespread occurrence of gold in the district warrants intensive search for higher values in larger quantities.

Development and Prospecting. Underground development was actually in progress at only one property during the months of July and August. This, the Moose mine, in the Gold Lake area, was consequently the only one that could be examined. The property was under the direction of Mr. John Redington, the well known mining engineer of Cobalt and Sudbury. On August 2 the shaft on this property was 100 feet deep, and the drift along the vein extended 71 feet to the southeast and 108 feet to the northwest. The shaft follows the vein which dips 70 degrees towards the southwest. There was also a short crosscut on the southeast drift leading into the foot-wall.

The vein, which was exposed on the surface for 130 feet northwest of the shaft, was covered by the dump and a swamp to the southeast of the shaft. It is in a shear zone in andesite porphyry, about 100 feet from the contact of this rock with an intrusion of granite. The vein varies in width according to the amount of replacement of the shear zone. The hanging-wall seems everywhere well defined against a slickensided wall of porphyry. But the foot-wall is irregular giving a width of solid quartz varying from 1½ to 6 feet. A second vein trending in a more westerly direction occurs 100 yards or so to the northwest. Its surface exposure showed a length of at least 125 feet and an irregular breadth averaging perhaps 3½ feet.

Nothing was ascertained as to the values in this second vein. In the vein in which the shaft was placed gold was not visible and the conditions were not suitable for sampling. It was reported that on the surface southeast of the shaft, values had been obtained up to $20 per ton. These, however, did not continue in the southeast drift at a depth of 100 feet. Values of $4 per ton in the shaft were reported as common for some distance from the surface.

The equipment, besides suitable camp buildings, consisted of two 40-horse-power boilers, one 3-drill Rand air compressor, and one Jenckes hoist. There was very little water in the workings. Wood was used for fuel and had to be drawn 6 miles. Freight from the railway at Riverton in winter or from Manigotagan wharf is not less than $35 per ton.

At a distance of a little more than a mile from the Moose mine are the Gold Pan and Gold Seal properties. Both were closed and only a few men were at the camp. Access could not be had to the shafts. The geological and surface conditions are similar to those at the Moose. High grade ore was reported to have been reached in these shafts prior to their closing in May. Mr. Marshall reports that they were being reopened late in September. The development work on these properties is evidently of substantial character, and, doubtless like that at the Moose, well directed. A limited amount of surface work had also been done on perhaps half a dozen other claims in the Gold Lake camp.

In the Long Lake camp similar surface work was found to have been done in four or five places, though at the time of my visit only one man was found in the district. The discoveries here are more recent and transportation is somewhat more difficult. The district, however, appears to be one of promise.

In the Rice Lake district no regular work was in progress but work is reported to have been previously done that is equal to that at Gold lake. One party was reported to be prospecting in the Hay Lake district. In all there were perhaps twenty-five or thirty men then in the entire district. In the autumn this number was somewhat increased.

While substantial work has been done on a number of claims the total amount is as yet very small relatively to the area under license. The great majority of the claims were found to be only staked, and even the staking was done in an indifferent manner.

The scarcity of labour owing to war conditions has doubtless been in part a cause of the lack of sufficient work being done. Difficulty of transportation has also contributed to the same result. Yet the total distance over which a trunk road is required is little if any more than 60 miles. The country is one of low relief and conditions for building a good wagon road suitable even for motor trucks seem favourable. While the lands belong to the Dominion Government, the development of the district would also benefit the province as well as the owners of mining claims. It would seem reasonable to expect that the combined interest from these three sources will soon find a way of building a road and of equitably distributing the cost. It is probable, however, that the chief cause

of the lack of work hitherto has been the inexperience of the many claim holders, who fail to appreciate the need of thoroughly prospecting and developing their claims themselves in order to prove their value, and hold them at absurd prices which discourage or prevent the entrance of development companies having capital and experience to prove the value of the district.

Other Possible Areas. While the extent of the different formations has not yet been mapped in detail there are considerable areas of the older series intruded by granite, that do not appear to have received any attention from prospectors. On Manigotagan river such an area occurs in the vicinity of Perry Davis rapids, about 19 miles from the mouth of the river. It extends for 2 miles up the river and similar rocks appear at intervals for nearly the same distance below this rapid. Also the section between Manigotagan post-office and Poplar rapids, a distance of about 2 miles in a direct line, appears to be largely underlain by rocks of a series older than the granite. This is on the west side of a large granite batholith on the east side of which are the rocks of Perry Davis rapids. It is not improbable that the deposits on Gold lake are near the east side of the same batholith, as the intervening area has not been worked out. While no discoveries of gold have yet been made in these areas, which are more accessible than those which have received more attention, they would seem to be good prospecting ground.

AREA BETWEEN RED RIVER AND EASTERN BOUNDARY OF MANITOBA, AND BETWEEN WINNIPEG RIVER AND NATIONAL TRANSCONTINENTAL RAILWAY, MANITOBA.

(*R. C. Wallace.*)

In this area no geological investigation had previously been made, except along the Winnipeg and Red rivers and in adjacent territory.[1] During August and September a reconnaissance survey of this territory was carried out, approximately six weeks being spent in the field. The writer was ably assisted by J. S. DeLury who, accompanied by M. W. Cooke, took charge of the territory east of Whitemouth river, and by A. A. McCoubrey in the western section.

The district falls naturally into two geological divisions: the granite area to the east and the limestone area to the west. It was one of the main objects of the investigation to define accurately the boundary between these two divisions. The western edge of the granite had heretofore been only provisionally mapped. With regard to its surficial geology, which is of considerable interest, the district must, however, be considered as a unit.

Pre-Cambrian Geology.

The granite of the eastern section is remarkably uniform in appearance. It is a medium-grained, reddish, biotite granite with a relatively small amount of ferromagnesian constituents; in places, with lessening ferromagnesian minerals it passes into a typical alaskite. Pegmatitic veins and irregular masses represent the final phase in the consolidation of this immense batholith. The gradation from the pegmatitic masses to the normal granite is in many places imperceptible. In only two localities are more basic phases prominent—in the southeast corner of the area, and in the northeast section along Winnipeg river from the Ontario

[1] Dowling (and Tyrrell), Geol. Surv., Can., Ann. Rept., vol. XI, pt. F, 1900.

boundary to point du Bois. Both areas illustrate the order of succession of igneous activity: (1) the effusion of basic lavas; (2) the intrusion of grey hornblende-biotite granite, now more or less schistose and in places gneissose; (3) the invasion of red granite above described; (4) the final consolidation of the magma in pegmatitic veins and masses.

A very coarse-grained modification of the red granite extends along the valley of Whiteshell river from the Cross Lake route to Winnipeg river. This may represent a deeper horizon in a batholith of large dimensions.

Closely associated with the basic lavas mentioned above is a fine-grained dark quartzite distinguishable in the field from certain phases of the lavas only with difficulty. While the sediments are undoubtedly later than the eruptives, they are placed, on stratigraphical grounds, in the same geological period. The eruptives are usually fine-grained, but occasionally a coarse-grained variety shows typical diabase structure.

In the area under investigation sufficient evidence is not available to determine the age of the red granite for correlation purposes. It is later than some fine-grained sediments, and, in the Star Lake district, southeast of the field investigated, it is later than a band of highly mineralized conglomerates and quartzites. Its remarkable freshness, as observed both in the field and under the microscope, and its comparative absence from strain would indicate that the rock belongs to a fairly late stage in the succession of Pre-Cambrian intrusions. The rock must be studied outside the limits of this field before it can be definitely correlated.

As a surface formation the granite extends farther west than it has hitherto been mapped. The whole basin of Whitemouth river lies in the granite, and fairly extensive patches of granite are found immediately east of Brokenhead river in the following localities:

SW. ¼	sec.	31,	tp.	15,	range	9, E.	1st	mer.
SE. ¼	"	13,	"	15,	"	8, E.	"	"
NW. ¼	"	30,	"	14,	"	9, E.	"	"
NE. ¼	"	26,	"	14,	"	8, E.	"	"
S. ½	"	26,	"	14,	"	8, E.	"	"
NE. ¼	"	3,	"	14,	"	8, E.	"	"
SE. ¼	"	9,	"	14,	"	9, E.	"	"

In these localities the boundary can be traced fairly accurately, as limestone is exposed on Brokenhead river as far east as the eastern limit of the Indian reserve. Northwards from Brokenhead river exposures are not found, except on Winnipeg river where the most westerly granite outcrop appears at the sawmill at the mouth of the river. The western margin of the granite there may be approximately mapped as lying along the course of Jackfish creek which flows through a low muskeg. In the southern part of the field the mapping can only be provisional. There, no granite is exposed west of Whitemouth river, and no limestone is exposed east of sec. 35, tp. 12, range 6, E. 1st mer. The rock surface is covered with clay and sand to such a depth that the deepest wells in the district—those at Molson and Vivian, both over 200 feet deep—do not reach solid rock. Data for accurate mapping are consequently lacking. The line is run provisionally in a direction slightly east of south along the valley of Brokenhead river to a point midway between Vivian and Hazel.

Palæozoic Formations.

East of Red river the Ordovician is the only Palæozoic formation represented. The Ordovician formation was subdivided by Dowling as follows:

Stony Mountain series.
Upper Mottled limestone.
Cat Head limestone.
Lower Mottled limestone.
Winnipeg sandstone.

The Stony Mountain series does not occur in this district, and the Cat Head limestone and Winnipeg sandstone have not been found exposed. The most important exposures not noted by Dowling are those of the Garson and Tyndall district where several extensive quarries have been opened in the Upper Mottled limestone to supply the demand for building stone in Winnipeg. Twenty years ago quarries were operated on a small scale at East Selkirk in the same formation. The exposures on Red river at Lockport and Lower Fort Garry are in slightly higher beds of the same division, while those on Brokenhead river on the Indian reserve, in the north harbour at Grand Marais and on the west side of Traverse bay (sec. 36, tp. 19, range 7, E. 1st mer.) must be referred to the Lower Mottled limestone. The sand beds on Traverse bay (secs. 30 and 31, tp. 19, range 8, E. 1st mer.) were considered by Tyrrell to belong probably to the Winnipeg sandstone, but are now found to be surficial deposits. The Winnipeg sandstone is an easily eroded formation. The tract of low-lying country in the valley of Jackfish creek probably represents the degraded surface of this formation.

The surface of the limestone is very uneven. Drilling records show that the level changes rapidly within short distances. A well-defined plateau extends eastwards from Red river through East Selkirk to the Garson quarries and to the northern part of tp. 12, range 6, E. 1st mer. Practically all the exposures occur on this plateau. From the evidence obtained from drilling on the plateau it would also appear that the Pre-Cambrian surface under the Palæozoic sediments was uneven, and that the early Palæozoic sea rested in a well-defined oceanic basin. At the quarries, the depth of the practically flat-bedded sediments is at least 100 feet whereas 15 miles northeast of that locality the granite rises 40 feet above the general level of the land surface.

Surficial Deposits.

Glacial and fluvioglacial agencies have been potent factors in moulding the topography of this area which, before Glacial times, had been fairly completely peneplaned. Evidence of fluvioglacial action is remarkably extensive. Eskers are found in many places throughout the area and extend in south-north, southwest-northeast, or southeast-northwest directions. The Birds Hill esker was studied by Upham in the course of his investigations of lake Agassiz in 1887 and again in 1909, and may be taken as typical of the ridges of the district. Many of the eskers reach greater dimensions than at Birds hill, but they all have the same general features. The ridges are high relative to their width, are irregular in height, and occasionally discontinuous. In section, the ridges have the characteristic features of river deposits, viz., diagonal bedding, abrupt transition from coarse-grained to fine-grained sediment, and sudden changes in the levels of the beds. It is clear that fluvioglacial activity was abnormally great in this area, and that true morainic deposition was somewhat limited. Many of the ridges in the western section of the field have now been mapped. The best examples of drumlins are those found resting on the higher cliffs that abut into lake Winnipeg on the south, as at Grand Marais point, where numerous boulders of unusually large size are strewn over the whole point. Similar boulder ridges occur between Grand Marais point and Victoria beach.

The slope of the land surface is towards the north. The northerly trend of the streams that drain the area has been only slightly modified, if at all, by the

ridges. Brokenhead river, for example, crosses quite a pronounced ridge in two places. Owing to the irregular disposition of the ridges, however, the drainage is somewhat retarded, and there still remain large undrained areas of swamp land, in which deposits of peat are now in process of formation.

Economic Geology.

In the Archæan area in the eastern part of the field no metallic deposits of economic importance have been found. There has been some prospecting of quartz veins north of Rennie, and on Winnipeg river east of point du Bois, but without success.

In the red granite certain areas are highly feldspathic, as, for example, patches of considerable size on Whitefish lake. When the extraction of potash from feldspars becomes an industrial process, these areas of orthoclase may prove of considerable value.

In the Palæozoic area the building stone of the Tyndall district is an important asset. It occurs in the Upper Mottled limestone and is quarried at Garson. The rock is a grey mottled limestone, the darker areas having been dolomitized, while the lighter—a fine-grained limestone—have not been metamorphosed. The colour contrast is sharp, the darker areas tracing a dendritic pattern, the general effect of which considerably enhances the value of the rock as a building stone. The rock is now somewhat extensively used for building purposes, all the larger government buildings and many of the more important city buildings in Winnipeg being constructed entirely of this stone. The Wallace Sandstone Quarries, Limited, of Garson, has a very extensive saw and planer equipment, and employed, during the summer of 1915, a staff of 180 to 200 men.

The granites of the eastern area have not been utilized for building purposes. The medium-grained pink varieties have a pleasing appearance, and under the microscope show no evidence of weathering or of foliation. These will probably yet be utilized as building and ornamental stone, in place of eastern granites which are fairly extensively used in the middle west.

Sand and gravel from the ridges at Birds Hill, Moose Nose, Oak Hummock, Beausejour, Vivian, Lewis, Molson, Milner, Sinnot, and east of Grand Beach have been used for constructional work on railways and highways. The ridges are so widely distributed over the area that the material is commercially available at almost any point in the district. At Beausejour the esker is composed entirely of sand with well-marked cross-bedding. A bottle-glass factory was established there in 1907, was incorporated as the Manitoba Glass Company in 1909, and was sold to the Dominion Glass Company in 1913. The factory is not now in operation. Sand from the same deposit is used in a sand-lime brick factory that has been in operation since 1906 and has a capacity of 20,000 bricks per day of ten hours. The limestone is obtained from Tyndall.

The stratified clays are used for purposes of brick-making at lac du Bonnet. The plant is well equipped for both the soft-mud and pressed brick processes. Beds of sand are interstratified with the clay, but not in sufficient quantity to supply the necessary sand admixture and sand has been taken in from outside points. Brick plants have also been operated at Whitemouth and East Selkirk. At East Selkirk coarse pottery was manufactured over twenty years ago.

Beside the railway track 4 miles southwest from lac du Bonnet a peat briquetting plant was erected in 1907 by the Interwest Peat Fuel Company of Winnipeg. The railway traverses the middle of the small bog from which the peat was to be manufactured. The factory ceased to operate in 1908 and the machinery has been dismantled.

SUPERFICIAL DEPOSITS AND SOILS OF WHITEMOUTH RIVER AREA, SOUTHEASTERN MANITOBA.

(*W. A. Johnston.*)

The Whitemouth River map-area includes townships 1 to 10, ranges 8 to 17, east of the principal meridian, in southeastern Manitoba, and embraces a land area of nearly 3,500 square miles. The area is bounded on the south by the International Boundary and on the east by the interprovincial boundary between Manitoba and Ontario.

This district, although the greater part of it is distant less than 100 miles from the city of Winnipeg and is well supplied with railways, has remained largely unsettled because of the wooded and swampy character of much of the area. At the beginning of the present year there were 6,690 quarter sections in the district available for homestead entry, nearly all of which are distant from a railway less than 20 miles. In addition, large areas of unimproved land are held for sale. During the past five years greater attention has been directed towards this district with a view to settlement because of the growing scarcity of prairie land available for homestead entry.

The object of the past season's field work was, chiefly, to investigate the agricultural possibilities of the region with a view to promoting and directing colonization. Special attention was paid to the possibilities of drainage and utilization of the swamp lands which form a large part of the area. Mapping of the different soils of the region was completed over an area of about 2,650 square miles and considerable information regarding the character of the soils of the remaining portion of the area was obtained.

A map on the scale of 2 miles to the inch, which will show the character and distribution of the different soils and of the forest growth, and a report embodying the results of the investigation are being prepared.

During the field season Frank L. Murphy, D.K.C. Strathearn, C. J. Baker, and C. R. Harris acted as assistants, to whose hearty co-operation the writer is much indebted. Acknowledgments are also due to the officials and employes of the railway department of the Greater Winnipeg Water District for information and assistance, and to many settlers in the district.

RECONNAISSANCE ALONG CANADIAN NORTHERN RAILWAY BETWEEN GOGAMA AND OBA, SUDBURY AND ALGOMA DISTRICTS, ONTARIO.

(*T. L. Tanton.*)

A reconnaissance was made, during the field season of 1916, of an area 177 miles long and 20 miles wide in the districts of Sudbury and Algoma, along the line of the Canadian Northern railway from Gogama to Oba station. The writer determined in a general way the boundaries of the major geological divisions, giving particular attention to those areas in which mineral deposits might be expected. Track surveys and micrometer surveys were made of many canoe routes which are either not shown or incorrectly shown on existing maps. A division of the party under Mr. I. E. Stewart studied the Pleistocene geology of the district. Mr. C. H. Freeman of the topographical division, made careful micrometer and plane-table surveys of some of the larger waterways. Previous

geological investigations have been made in the area covered by this season's work by Dr. R. Bell, Mr. J. A. Dresser, and Dr. W. A. Parks.

The writer was ably assisted in the field by G. Hanson, T. L. Gledhill, and W. S. Mills. The Eastern Lands department of the Canadian Northern railway extended the courtesy of free transportation over the railway.

REGIONAL GEOLOGY.

The solid rocks of the region may be classed under three headings: (1) an old volcanic complex, with minor amounts of highly altered sediments; hitherto referred to as the Keewatin; (2) batholithic intrusions of granite and gneiss; and (3) later dyke rocks.

Volcanic Complex Areas.

On account of the important mineral discoveries which have been made in areas of the volcanic complex elsewhere in Northern Ontario, the following note may be of value to prospectors working in the district.

The rocks of the district which are included under this designation comprise a complex of lava flows, chiefly of the andesitic type, and hornblende, biotite, and sericite schists; basalt, peridotite, and quartz porphyry dykes; banded pyroclastics; and banded iron formation. The age relations of these various rocks have not been determined, but all are older than the great granitic batholiths. The distribution of the volcanic complex within the district is as follows:

A band, averaging three-fourths of a mile in width, extends from the southern end of lake Mattagami to Schist lake, crossing the Canadian Northern railway at mileage 81 north from Capreol.

A large irregular area is crossed by the Canadian Northern railway between mileages 128 and 144 from Capreol. This decreases in width as it is traced northeast and east, having a width of 2½ miles in eastern Kenogaming township. The width increases as it is traced to the southwest from the railway; at a distance of 20 miles away it extends from Whigham to McOwen townships, a width of approximately 22 miles.

A large area of these rocks is crossed by the Groundhog and Pishkanogami rivers for the last 20 miles of their courses before their junction. This is a southward extension from a huge volcanic complex area lying to the north.

An area having a width of at least 3 miles was observed at the southwestern end of Missinaibi lake. The trend of the rocks is north 20 degrees west.

A band of schists nearly half a mile in width crosses the small lake east of Mang lake, trending north 20 degrees east.

A band of volcanic complex 1½ miles in width crosses Missinaibi river 10 miles north of the Canadian Northern railway. It extends northwest and west to Kabinakagami lake, crossing the railway at Neswabin. Two other bands were found to the south of this in the Kabinakagami Lake district, the trend being parallel.

A small area of banded mica schists occurs at the outlet of Kabinakagami lake; and a belt of similar rocks, 4 miles in width, occurs 15 miles north in Talbott township and along the valley of Mattawitchewan river in Scholfield township, the trend being east and west.

MINERAL OCCURRENCES.

Very little prospecting has been done in the district and no workable mineral deposits have been reported as yet. The following note describes the mineral occurrences discovered by the party this season, and also the previously discovered ones which were examined.

Gold.

Gold occurs in quartz veins cutting a ferruginous dolomite and chlorite schist, on a claim staked by D. Arkell, 1½ miles north from the northeast corner of Penhorwood township. No free gold is visible, but a sample taken across a vein by the writer yielded upon assay 0.02 ounce to the ton. Several large quartz veins have been staked in the east-central part of Kenogaming township, on the shores of Aquesqua and Kenogaming lakes, but no gold is known to occur in any of these. Several samples collected by the party showed no gold content upon assay.

Copper.

Chalcopyrite occurs abundantly in a zone 5 inches wide, in a quartz vein cutting chlorite and sericite schist, at a point 30 chains north on a trail from Portage bay near the north end of the northeast arm of Mattagaming lake. Two showings of chalcopyrite were found in quartz veins cutting altered andesite, on the east and west shores, respectively, of the northwest arm of Mattagaming lake, approximately half-way between the north end of the arm and its junction with the northeast arm. A quartz vein, cutting a dyke of Nipissing diabase, was abundantly mineralized with chalcopyrite for a width of 8 inches on the southeast shore of Missinaibi lake, 3 miles southwest from Fairy point. Other smaller deposits of chalcopyrite were seen; on the east shore of Mesomekenda lake 4 miles north of its south end; in a railway cutting near mileage 126, half a mile from Tionaga; also in railway cuttings a few chains west from the bridges over White Duck and Slate Rock lakes, respectively; on the east shore of Slate Rock lake, southwest from the railway crossing; in a railway cutting 39·6 miles west of Foleyet; also at milepost 93 west from Foleyet; on a hill about 20 chains southeast from the railway bridge over Pishogen river; and in rock cuttings on the Algoma Central railway at mileages 235, 235½ in the township of Hawkins and at 248½ in the township of Franz. In the majority of cases, the chalcopyrite was found in quartz pegmatite veins near the borders of the volcanic complex areas; and in a few cases, it is associated with diabase dykes.

A deposit of chalcopyrite has been reported in Connaught township, about one mile southwest from the west end of Okawakenda lake, on property held by John Mataris. The ore occurs between slate and greenstone in a schisted shear zone impregnated with quartz veins. The vein material possesses a maximum width of 100 feet and has been traced for several hundred feet.

Nickel.

The iron formation on the Benbow-Wallingford property in the northwestern part of Kenogaming township, carries abundant pyrrhotite. Assays of this material show the presence of nickel in very small quantities.

Lead.

A lead deposit of economic interest has been reported as cutting the iron formation on a claim north of Sagitosh lake. The vein averages 9 inches in width and consists entirely of finely crystalline galena, sphalerite, and chalcopyrite. An assay of this material gave the following results:

Silver	1.32 ounces per ton
Lead	69.28 per cent
Copper	1.25 " "
Zinc	1.03 " "

Other occurrences of galena were found in the course of the exploration in an aplite dyke cutting the diabase in the rock cut 93 miles west of Foleyet, and at the contact of a diabase dyke with the volcanic complex near the east end of Schist lake.

Zinc.

Zinc blende in very small amount was discovered in association with the galena at mileage 93 west from Foleyet on the Canadian Northern railway and also in a quartz vein cutting a member of the volcanic complex on the right bank of Fire river in Hayward township, between the 6-foot and 20-foot falls.

Iron.

Two large bodies of banded iron ore have attracted the attention of mining men in this district. One of these crosses the Groundhog river, striking east and west, half a mile north of the Canadian Northern Railway bridge; the other occurs to the north of Sagitosh lake. The iron ore at the first locality is chiefly magnetite whereas, at the second, it consists chiefly of closely intermingled magnetite and pyrrhotite with, locally, considerable amounts of pyrite; and several million tons have been blocked out by diamond drilling in both localities. In the first mentioned deposit the iron content runs between 34 and 42 per cent; it is low in phosphorus and sulphur, and contains no titanium. The second deposit runs between 40 and 50 per cent in iron; it is low in phosphorus and free of titanium, but contains as much as 15 per cent sulphur.

Banded iron formation was observed as follows: at several points in Keno-gaming and Penhorwood townships; on the boundary between them, 15 chains south of the 7½ mile-post; in a rock cut on the railway 65 chains west of mileage 128 north of Capreol; half a mile north of Slate Rock lake; on the Muskego river near the southern boundary of Ivanhoe township; and on the west shore of Groundhog lake near its south end. All of these outcrops were too lean to be of commercial value.

Molybdenite.

Molybdenite was found in small quantities in pegmatitic quartz veins, cutting the volcanic complex, in three localities near Oba; on the most easterly point of the main northern peninsula in Kabinakagami lake; on the west bank of Oba river opposite mileage 236½ on the Algoma Central railway; and on a hill west of Pishogen river, 1 mile north from Canadian Northern railway, mileage 96½ west from Foleyet.

Asbestos.

Picrolite, or stiff-fibred asbestos, occurs in an altered peridotite dyke, on the north side of the railway 10 chains east from the bridge over Groundhog river. No asbestos of commercial value was found.

Mica.

Muscovite occurs abundantly in the pegmatite dykes along the banks of Mattawitchewan river, in the southern part of Scholfield township. The plates range up to 4 inches in diameter.

NORTH SHORE OF LAKE HURON, ONTARIO.

(*W. H. Collins.*)

In 1914 the writer began a study of the Pre-Cambrian terrane along the north shore of lake Huron, mainly with the intention of revising the stratigraphy of the Huronian formations, which are unusually well developed there, and correlating them with like formations which occur in Cobalt, Sudbury, and other areas in northeastern Ontario. Last summer (1916) this investigation was carried far enough to admit of discontinuing field work and reporting finally upon the results obtained. The final report is now being prepared, as are also three geologically-coloured maps for which the necessary data have been obtained. One of these maps will represent an area of 625 square miles extending from Ekoba on the Canadian Pacific railway to Thessalon; another an area of 1,000 square miles from Dean Lake to Cutler, and the third an area of 375 square miles from Espanola to the vicinity of Naughton. Only part of each area, however, has been geologically mapped.

Valuable assistance was given throughout the season by Dr. T. T. Quirke of the University of Minnesota and Mr. O. D. Boggs, Kingston, and for part of the time by Mr. W. F. Chisholm of St. Francis Xavier's college, Antigonish, Nova Scotia. This opportunity is also taken to acknowledge kindnesses from Mr. J. H. MacDonald, of the MacDonald and Moore Lumber Company, Blind River, and Mr. T. J. Robinson, of the Victoria Harbor Lumber Company.

GENERAL GEOLOGY.

The results obtained from studying the stratigraphy of the district have been partly stated in Museum Bulletins 8 and 22, and the final report embodying all is already under way. Consequently, it is unnecessary to do more here than announce the main conclusions. The formational sequence was found to differ in few respects from that elaborated sixty years ago by Alexander Murray of the Geological Survey; but within this sequence an erosional unconformity of considerable importance was found, which divides the Huronian into a lower (Bruce) series and an upper (Cobalt) series. It was also found that the Huronian, in northeastern Ontario, hitherto regarded as a comparatively undisturbed series of formations, was, in the neighbourhood of lake Huron, mountain-built and intruded by granite-gneiss batholiths during late Pre-Cambrian (apparently Keweenawan) time, and eroded to an old-age topography before the Ordovician. This mountain-building disturbance appears to have extended eastward and southward in the direction of eastern and central Ontario, where, hitherto, its existence does not seem to have been suspected, and where, it is consequently conceivable, some modifications in the present geological conceptions may be rendered necessary by its discovery.

ECONOMIC GEOLOGY.

In the course of this year's field work a number of ore deposits of possible commercial value were examined. A somewhat fuller account of these is given below.

Gold.

Howry Creek Gold Claims. Gold-bearing quartz veins were discovered on Howry creek about five years ago. Since then the discoverers, F. Steep, Chas. Bousquet, S. Bousquet, and others have prospected the neighbourhood for more

veins and have done considerable surface development upon the more promising ones. This year some of the claims are being worked, under option of purchase, by J. Wilson of Massey and A. L. Kemp of Gore Bay, Ontario. These claims are located on the north side of Howry creek, a tributary of Whitefish river. They lie close to the western boundary of timber berth No. 90, and about 35 miles southwest of Sudbury. They are most easily reached from mileage 64 on the Algoma Eastern railway, the canoe trip across Charlton lake and up Howry creek requiring only two and a half hours.

Of the various properties only one, owned by Mr. C. Bousquet, was examined by the writer; but this one was said to be fairly representative of the camp as a whole. The country rock is mainly Huronian quartzite. Streaks of greywacke occur in places, and intrusive diabase is common in the vicinity, though not on the property examined. The veins strike east and west and dip vertically or steeply. On Mr. Bousquet's claim one vein had been stripped for 300 feet without finding its termination either way. It was reported to be traceable at intervals across several claims. Its course is rather irregular and its width varies from a few inches to 4 feet. The gangue is schistified country rock in places but for the most part it is a mixture of white quartz and a bluish-grey carbonate which weathers to limonite. Arsenopyrite, pyrite, and occasional particles of free gold are present, the sulphides being either disseminated through the gangue or aggregated locally along the vein in bodies up to a foot in thickness. Test pits 15 feet deep showed the same kind of ore at that depth. No assay samples were taken, but the assay sheets showing the result of sampling upon a neighbouring claim, which were shown me by Mr. Kemp, indicate a gold content ranging from $1.50 per ton up to very high values.

On one of the claims owned by Mr. Steep, not visited, there is reported to be a series of ten parallel veins 10 to 30 feet apart and mineralized in much the same manner as above described.

Iron.

Iron Ore in the Bruce Limestone. While tracing the various Huronian formations across timber berths 149 and 155, about 15 miles north of Spragge station on the Canadian Pacific railway, the base of the Bruce limestone was found to contain a lean iron formation. The Bruce limestone has been examined at many places in the North Shore district, but nowhere except in the locality mentioned was it found to contain more than 1 or 2 per cent of disseminated iron—just enough to give weathered surfaces a reddish colour. The presence of iron ore in this locality must be regarded, therefore, as a special feature of the Bruce limestone.

In timber berths 149 and 155 the Huronian rocks dip about 20 degrees north, forming the southern side of a shallow syncline. The Bruce limestone constitutes the eroded top member of the Bruce, or lower Huronian series, and is unconformably overlain by the thick basal conglomerate of the Cobalt, or upper Huronian, series. Originally about 150 feet thick, it has been eroded to half or less that amount, only the basal and middle parts remaining. The base, which rests upon the Bruce conglomerate, is mainly siliceous, gradually passing upward into the more calcareous middle part by the alternation of the siliceous layers with calcareous ones of increasing thickness, until a limestone carrying about 60 per cent carbonate is reached. The formation is exposed for a width varying from 20 or 30 feet to several hundred feet and extends east and west across the middle of the two timber berths.

The iron formation occurs in the base of the Bruce limestone. Owing to the lack of continuous exposures its thickness could not be ascertained accurately,

but it is apparently about 15 feet. In that thickness the siliceous material which normally forms the base of the Bruce limestone carries iron ore either disseminated through it in small grains, or in fairly pure layers ranging from paper-thinness to 2 or 3 inches thick. The ore is black, finely crystalline, and faintly magnetic, evidently consisting mainly of hematite. A sample taken from a band 2 inches wide, assayed by the Mines Branch, yielded the following results:

Fe	TiO_2	P	S	SiO_2
40·26	0·34	0·037	0·040	31.08 per cent.

The proportion of ore to siliceous rock is probably not more than 1 to 4 at any point observed, consequently the iron formation is much too lean to be merchantable. There is a possibility that concentration may have occurred somewhere in a range as extensive as this. Iron formation was observed at intervals along the strike of the Bruce limestone for over 2 miles, beginning about a mile within timber berth 155 and extending eastward into timber berth 149. The stratified character of the formation should render its exploration along the narrow belt of outcrop comparatively simple.

LONDON AREA, ONTARIO.

(*J. Stansfield.*)

A period of six weeks was spent by the writer during the summer season of 1916 in completing the mapping of the London district. The area mapped includes approximately 806 square miles and is bounded by the meridians of 81° and 81° 30′ west, by lake Erie, and by an east and west line 1½ miles north of the line 41° 05′ north latitude. The mapping was done on the scale of 1 mile to 1 inch, using the topographical map of the Militia Department as a base (Port Stanley, St. Thomas, and part of Lucan sheets).

The writer wishes to express his thanks to the engineer in charge of the waterworks of London, for his kindness in supplying information with regard to the progress of the works under his charge, and also to Mr. J. Harvey of Canboro, Messrs. C. and J. Wright of Petrolia, and Mr. G. N. Smith of Dorchester, for details with regard to borings for water undertaken by them. For details with regard to boring operations for gas or oil the writer is indebted to Mr. J. J. Irvin of Dunville, Mr. J. H. Patterson of Dunville, Mr. Leo. Wilson of Delaware, Mr. M. E. Rose, and Mr. D. C. Baxter.

A series of eleven determinations of beach elevations have been made, which show that several distinct pro-glacial lakes existed in this district. Of these lake Whittlesey has undoubtedly left the strongest shore deposits.

The water situation in London was the cause of some anxiety in the first two weeks of July. As a result of a threatened shortage conservative methods for use of the available water were adopted, so that the difficulty was removed. At the same time the water commissioners have instituted a policy of preparatory prospecting for further supplies of artesian water from the intra- and sub-glacial gravels, which will doubtless meet with success. This seems to be the most promising source of additional supply, when the outlay involved is considered.

Considerable prospecting for oil and gas has been done in the district during the past year. Dry holes have been drilled at a point about 2 miles east of Port Talbot on lot 12, concession XIII, Yarmouth township, and several dry holes have been drilled in the valley of the Thames near Delaware. One hole

in the village of Delaware had a showing of gas but no details as to the yield are to hand. Another well situated about a mile north of the centre of Delaware village has a very large flow of sulphur water and a small yield of a dark brown oil. No details as to the gravity or other qualities of this oil are to hand but the yield of the well is not important. Drilling on lot 4, concession I, North Dorchester township, met with a slight showing of gas in what appears to be the Salina formation. Drilling was to be continued but the results of this work are not to hand.

The brick and tile industry was quiet during the past season, but most of the plants were in operation.

A number of soil samples were collected to illustrate the main types of soil to be found in the district. The past season was not very successful with regard to field crops. The months of May and June were marked by heavy and continuous rains which rendered the ground so wet that seeding could not be attempted with profit. This wet weather was followed by very hot dry weather in the month of July, which baked the soil so hard that seeding could not be undertaken in some cases. Most of the crops were considerably below the average, particularly the potato, oat, and corn crops.

INVESTIGATIONS IN ONTARIO.

(*M. Y. Williams.*)

General Statement.

When the final report on the Silurian of southwestern Ontario was begun by the writer, problems were found which necessitated additional investigation in the field. The required work took approximately seven weeks, or from June 28 to July 6 and from August 22 to October 1.

Considerable interest having been aroused concerning the limestones at the north end of lake Timiskaming, as a result of the work done by the writer in 1914 (see Geol. Surv., Can., Mus. Bull. No. 17), it was decided to send a party into the region to study it in detail. George S. Hume, who has assisted the writer during the past two summers in mapping the Silurian of southwestern Ontario, was chosen to do the work under the writer's supervision.

Mr. Hume and the writer started a reconnaissance of the region on June 9 and continued work together until June 28, after which Mr. Hume continued the work alone until October 6. Mr. Hume's report on this work is submitted below.

The writer is indebted to Mr. Wm. Kemp of Silver Water, for transportation to and from Green island, and for hospitality at the lumber camp on the island, which is under his charge.

Silurian of Southwestern Ontario.

During the period June 28 to July 6 the writer visited localities near Gore Bay and Kagawong, Manitoulin island, and explored Green island in lake Huron, near the western end of Manitoulin island. That strata of Guelph age might outcrop on Green island seemed probable, as the rock at Quarry point, about one mile to the northeast, is upper Lockport. The age of the strata in question, however, is Lockport, as shown by the absence of Guelph fossils and the presence of the following, which are common in the Lockport: *Diphyphyllum multicaule* (Hall) ? *Syringopora* sp., *Favosites gothlandicus* (Fought), *Halysites catenularia* (Linnæus), *Pentamerus oblongus* Sowerby, and *Orthoceras* sp.

During the period August 22 to October 1, the divisions of the Cayugan group occurring in Ontario were studied and mapped. These divisions comprise the formations lying between the Guelph formation and the base of the Devonian system. In addition the mapping of the Silurian formations near Hope Bay and Cape Croker, on the Bruce peninsula, was revised.

The work on the Cayugan group was begun by a study of sections between Mertensia and Buffalo, N.Y., and afterwards the divisions were traced into Ontario. Thanks are due Professor Chadwick for his courteous assistance during the first ten days of the work. Without his guidance, little could have been accomplished in the time allotted to the study of the New York sections.

The Cayugan group of the Buffalo region includes, according to the writer, the Akron[1] dolomite and the Salina formation, the divisions of the latter being the Bertie waterlime and the Camillus shale.

The thicknesses of the divisions, as taken from the core[2] of a well drilled in north Buffalo, are as follows:

Akron dolomite	7 feet.
Bertie waterlime	43 "
Camillus shale containing gypsum	387 "

These divisions are clearly defined as far west as Ridgeway, beyond which the Akron and Bertie have not been separated.

Between Springvale and Innerkip, a distance of more than 30 miles, only one outcrop is known to the writer. This is about 12 miles northwest of Hagersville and is either Akron or Bertie. At Innerkip, buff dolomite is exposed in a quarry south of the station. A thin bed of sandstone one inch or less in thickness, separates the beds into an upper and a lower division. In the upper division a *Whitfieldella* was found, which is probably the same as that compared by Grabau with *W.? nucleolata* (Hall), from the Akron. Between Innerkip and Walkerton, a distance of 68 miles, no outcrops of upper Cayugan rocks are known. The Detroit River series, referred to the Devonian system, outcrops at Woodstock, Beachville, St. Marys, Gorrie, and 4 miles west of Walkerton. As the lower Detroit River and the upper Cayugan rocks are very similar, their separation is difficult. Between Walkerton and Paisley, the Akron-Bertie dolomite, or its northern equivalent, and the Camillus shale are present. Between Paisley and Southampton no outcrops are known. Continuous sections are absent in this northern region and no complete measurements could be made of the divisions which are based entirely on superposition and lithologic characters. It appears clear, however, that the Akron-Bertie underlies the Detroit River series and so occupies the same position as the lower Monroe of the Detroit River region.

ECONOMIC GEOLOGY.

The Cayugan formations furnish salt and gypsum, and dolomite for road-metal and lime manufacture.

Salt. The salt occurs in beds near the middle of the Camillus shale, and is obtained as brine from wells in the regions along lake Huron, river St. Clair, lake St. Clair, and Detroit river. The salt industry was not investigated by the writer this season.

Gypsum. Gypsum occurs as lenses in the upper part of the Camillus shale of Niagara peninsula and is mined at Caledonia by the Alabastine Company,

[1] *Akron* is used instead of *Cobleskill* for the upper division which has not been satisfactorily correlated with the Cobleskill of eastern New York. The upper dolomite at Buffalo and Akron are clearly equivalent.
[2] Bull. N. Y. State Mus., No. 45, p. 115.

Limited, of Paris, Ontario, and at Mt. Healy by the Crown Gypsum Company which has its mill at Lythmore, Ontario. The old workings, 4 miles southeast of Cayuga and at Paris, have been abandoned. The gypsum beds are generally from a few inches to 3 feet in thickness, two or more beds occurring at some localities, with several feet of shale or argillaceous limestone between them. At some horizons, there are enough nodules of gypsum present in the beds of shale, to make them valuable as a source for land plaster. No alabaster suitable for work in the arts has been found.

Road Metal. A good quality of road metal is obtained from the Akron-Bertie dolomite at Ridgeway, Dunnville, and Cayuga. At Byng, south of Dunnville, a municipal quarry has been in operation for some time and the stone is said to have given good satisfaction.

Lime. The Akron-Bertie dolomite has been burnt for lime at Springvale, Innerkip, and on Saugeen river 2 miles south of Pinkerton. The quality of the lime is reported to have been good, but lack of wood for fuel and competition with larger companies have resulted in the closing down of the kilns.

CO-OPERATION WITH THE BORINGS BRANCH.

In September, according to instructions, superintendents of gas companies at Dunnville, Simcoe, Brantford, Woodstock, and St. Thomas were interviewed with the object of getting their co-operation with the Boring Record branch, under the charge of E. D. Ingall, in gathering information from the wells that are bored under their supervision. Courtesy and appreciation of the purpose of the work were shown at each office visited, and assistance was promised by those in charge of boring operations.

The writer is indebted to the Boring Record branch for much valuable information, obtained both from the files and the series of samples taken from wells. A great quantity of additional information may be obtained from the gas companies and, in view of the value of the oil and gas industry, it is most important that our information should be made as complete as possible.

Palæozoic Rocks of Lake Timiskaming Area.

(*G. S. Hume.*)

Early Palæozoic rocks have long been known in the lake Timiskaming area, but during a brief reconnaissance study made by M. Y. Williams in the autumn of 1915 additional formations were discovered. A report of this appears in Museum Bulletin No. 17, Geological Survey, Canada. Later it was proposed that the writer should undertake a more detailed study of this area and, consequently, the summer of 1916 was spent mapping the geological formations and collecting palæontological material.

My thanks are due to M. Y. Williams, under whose direction the work was undertaken, and who spent three weeks at the beginning of the summer making a reconnaissance of the whole area. To Mr. A. A. Cole, mining engineer of the Timiskaming and Northern Ontario railway, I am indebted for suggestions regarding possible structures. Mr. George King, well driller, of New Liskeard, gave much information regarding extensive well drilling that he has done in this area. I also wish to thank Mr. E. M. Loring of Haileybury, through whose generosity I obtained the records of several diamond drill holes in an area where the outcrops of Palæozoic rocks are very limited.

Geological Survey Canada

Catalogue No 1671

The Palæozoic rocks of lake Timiskaming and vicinity

Scale of Miles

To accompany Summary Report by G. S. Hume, 1916

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Change in Map.

The chief change in the geological map of the area was made in the region extending northwest from New Liskeard and drained in its more southern part by Wabi creek. This part has previously been mapped as underlain by greywacke and conglomerate, but from drill records now available, it was found that the rock is Palæozoic limestone Lockport, in age, and covered by a thick mantle of banded Pleistocene clay.

GENERAL GEOLOGY.

Faulting.

A very flat area, only a few miles in width, extends northwest from New Liskeard, rising gradually until it reaches a point 2 miles north of Earlton station, where an outcrop of Lockport dolomite occurs. This area is cut by the valley of Wabi creek and the smaller valleys of several of its tributaries. It is bounded on the west by a very pronounced and continuous ridge which is mostly clay on its margin but has scattered outcrops of Lockport dolomite. The ridge is in line with the straight western side of lake Timiskaming, and is undoubtedly the continuation of the fault described by Miller[1] and later by Williams.[2] Where Palæozoic strata occur on the edge of this fault scarp the beds are tilted at high angles and much fractured.

No Lockport dolomite occurs west of the fault scarp, but farther west and at higher elevations than the Lockport outcrops in the vicinity of New Liskeard and Haileybury, Ordovician rocks are clearly exposed in two localities, separated by Timiskaming conglomerate of Pre-Cambrian age. Northwest of New Liskeard and west of the fault, the country is dotted with knobs and ridges of Pre-Cambrian rocks, but in places there are flat areas of clay of considerable extent. The fault scarp can be traced continuously from the north end of lake Timiskaming at New Liskeard to 4 miles west of Thornloe, where it gradually decreases in height and ultimately vanishes.

Extent of the Palæozoic Rocks.

The best exposures of Palæozoic rocks occur on the islands and shore of lake Timiskaming, but others are scattered through the country and on some of the streams north of the lake as far as Englehart. The southern limit of the Palæozoic area is on Bryson island, where a calcareous sandstone enclosing Pre-Cambrian pebbles rests on Huronian quartzites. On the eastern shore, the Quebec side of the lake, the country rock is for the most part much the same as that on Bryson island, and outcrops are confined mostly to small isolated areas on the shore, with only slight extent inland. In places only the basal beds are shown and they consist of very coarse conglomerate of sea-green Pre-Cambrian quartzite pebbles, cemented together by calcareous sandstone.

Age of the Strata.

The Ordovician rocks to the west of New Liskeard and Haileybury have a fauna, part of which has been correlated with the Black River as developed on Allumette island in the Ottawa valley. They have also a few fossils similar to those which Dr. A. F. Foerste has found in the Black River rocks of Cloche island in lake Huron. The fauna collectively is in many respects the same as

[1] Rept. Ont. Bureau of Mines, vol. XIX, pt. II, p. 108.
[2] Geol. Surv., Can., Mus. Bull. No. 17, p. 7.

that of the Galena-Trenton of Wisconsin-Minnesota, with the marked difference that in the Timiskaming region there is an abundance of single and compound corals of considerable variety. Usually the coral fauna is not seen below latest Ordovician horizons, but here it is present in the Black River-Trenton formations. The top of the Trenton was not seen, but the thickness of the formation is possibly 50 feet.

No Richmond was found in the area, although it might be expected to occur. It is quite probable that it is present, but is completely covered over by higher formations or Pleistocene clay. The Richmond will again be referred to in describing the Cataract formation.

At Dawson point there is a section 310 feet in thickness. For the most part this is made up of Lockport dolomite, with some thin-bedded Cataract(?) limestone at the base. The Lockport is very fossiliferous at some horizons, particularly near the top, where the beds are of a thick, massive type. An interesting feature of the Lockport here is that it contains a layer of hard sandstone about 1·5 to 2 feet thick, below which occurs thick-bedded sandy dolomite grading downward, into buff-coloured dolomite. This bed of sandstone appears to be a persistent layer at the same stratigraphic position over the whole Timiskaming area. It was found first by Williams on Mann or Burnt island during reconnaissance study. Good sections occur at several places on the island which is underlain by Lockport, with the possible exception of the southern end, where Cataract may be present. Another occurrence of this sandstone horizon is at a point to the southeast of Thornloe, where a small escarpment of Lockport about 1·5 miles long appears as the continuation of a clay ridge running in a general northwest direction.

At Dawson point on the east side of lot 5, con. I, Harris tp., the Cataract formation occurs on the shore of the lake as green shaly or limy material, with mud-cracks and without fossils. Above this are thin-bedded limestones which weather to a brownish colour. Among the fossils in these beds ostracods of Cataract (?) species are especially abundant.

At a still higher elevation occur greenish, thin-bedded limestones, and these in turn grade up into buff-coloured limestones, some of which are finely laminated and without fossils. As the region north of lake Timiskaming is very generally covered with a thick deposit of Pleistocene clay, it is not surprising that so few outcrops were discovered. However, on the southeast branch of Blanche river (or Jabetsch creek, as it is commonly known to settlers) there is a small fall due to an outcrop of Cataract. The fall is approximately 2 miles south of Englehart and on lot 9, con. III, Evanturel tp. Here the character of the Cataract is much the same as that at Dawson point, and again ostracods are the predominant fossils, although a few lamellibranchs and brachiopods also occur.

From the limited number of sections of Cataract found in this area, no estimate of the total thickness of this formation could be made. However, at Englehart, drill records show that limestone occurring below the Lockport and above the Trenton had a maximum thickness of 70 feet. The upper 35 feet of this limestone is a bluish to greenish colour similar to that which was seen in the outcrops of the Cataract formation, and the lower 35 feet is of a brown colour. Since it is probable that Richmond occurs in the area, it seems likely that the upper 35 feet is Cataract, while the lower 35 feet is Richmond.

Although no Palæozoic formation higher than the Lockport was found in this region, it seems quite likely that the area was covered by seas of later periods. It is probable that the Guelph seas extended this far east, and likewise that in at least middle Devonian time the Timiskaming area was completely covered by seas. However, if any Palæozoic deposits later than Lockport were ever present, they have been subsequently completely removed by erosion.

ECONOMIC GEOLOGY.

Water Supply.

In the area of the Palæozoic rocks an insufficient water supply is often a very disturbing problem to settlers, and is due to the mantle of Pleistocene clay. Wabi creek flowing southeast to New Liskeard, and Blanche river on the eastern part of the area are rather sluggish streams for some distance back from the lake, and flow for the most part over clay. A part of the clay is carried in suspension and the waters have a dirty yellow colour. Surface wells are apt to go dry in the summer, and good drinking water may become very scarce.

In certain areas, however, it has been found that by boring through the Pleistocene clay to the Palæozoic limestone underneath, good water can usually be obtained in abundance, and in some places artesian wells are found. In the area extending northwest from New Liskeard, the clay has a thickness of 100 to 200 feet, and rests on limestone which dips southwest. In this area several of the wells drilled have proved to be flowing and in many more the water rises almost to the surface. The town of New Liskeard obtains drinking water from an artesian well in the town itself and from springs and wells on the west side of Dawson point.

In the district around Earlton also, considerable well drilling has been done, and in the majority of cases satisfactory wells have been obtained, although few of them are artesian.

Brick Industry.

All through the clay belt, the Pleistocene clay is remarkable for its even stratification. The bands are alternately of light and dark colour, the light layers containing more lime. Attempts have been made to use the clay for the manufacture of brick at New Liskeard and Haileybury. The clay in the upper 6 feet contains many limy nodules, apparently the result of percolating waters, and where these are not removed from the brick clay, white spots result which spoil the appearance of the bricks and later cause them to burst, owing to the slaking of the lime of the nodules. Even when the clay is obtained from a deep pit where no nodules are present, it is found that the bricks are of an inferior quality, owing to the large content of lime. To overcome the difficulty, sand was added, but owing to its scarcity in this district, the cost of production of brick was too high for competition with outside firms. Lately the Haileybury Brick and Tile Company made the discovery that the finely ground diabase, so plentiful at Cobalt, could be used in place of sand. By experimentation, a suitable mixture of ground diabase and clay has been found and bricks much superior to those formerly produced are now being made. The increased cost of production has been more than overcome by the increase in number of good bricks obtained.

Limestone.

To the west of Haileybury the Farr quarry is being worked in the Trenton formation. The stone is broken into fragments and shipped by rail to Iroquois Falls, where it is used in the manufacture of paper pulp in a sulphite plant. According to information obtained from the report of A. A. Cole, mining engineer of the Timiskaming and Northern Ontario railway, the amount of stone shipped from this quarry during 1915 was 2,401 tons.

Lime. All the lime that has been produced in the area has been made from the Lockport formation. At present a kiln situated west of New Liskeard and owned by Mr. W. Taylor is the only producer of lime in commercial quantities.

Analyses of the limestones gave the following results:

Analyses of Limestone from Haileybury and New Liskeard.

	Farr's quarry.	Taylor's quarry.
Insoluble residue	5·06	2·96
Aluminum and iron oxide	0·87	1·87
Calcium oxide	44·81	31·98
Magnesium oxide	5·90	10·86
Carbon dioxide	42·40	51·85
Total	99·04	99·52

G. S. Hume, collector and analyst.

Building Stone. Rock of both the Trenton and the Lockport formations has been used as building stone to some extent.

In Haileybury several buildings, chief among which is the cathedral, have been made of stone taken from Farr's quarry, west of the town. The stone, which is Trenton in age, is of a bluish grey colour on the fresh surface and of a pleasing appearance, but, owing to the great thickness of the individual beds, the stone is not readily obtained in blocks of the proper size and with smooth surfaces.

A good quarry for building stone has been opened on the east side of Mann or Burnt island, from which stone was taken to build the public library of New Liskeard. The stone is buff to cream coloured and occurs in the quarry in uniform beds 6 to 8 inches thick. Jointing too is well developed and fairly regular, so that waste in quarrying is not excessive. Owing to the ease with which the stone may be extracted and to the fact that it can be transported by boat to any of the towns around the lake, this quarry should become of considerable commercial importance in the near future.

ROAD MATERIAL SURVEYS IN ONTARIO AND QUEBEC.

(*L. Reinecke.*)

During the season of 1916 surveys were made for material available for the surfacing of portions of certain main interprovincial roads in the provinces of Ontario and Quebec. Since the inception of the work on road materials in 1914 the Geological Survey has made surveys in localities where the highway departments of the two provinces have thought that the surveys would be of the greatest use, and has furnished the provincial engineers with advanced data of the results obtained at the very earliest opportunity, and long before the printing and distribution of the final reports. It is hoped, that, as the work is extended into the other provinces, it will be possible to coöperate as closely with those who are building roads there.

During the winter of 1916 and 1917 a laboratory for the testing of road materials has been established in the Mines Branch of the department. The laboratory is well equipped and it will do much toward increasing the effectiveness of the work. Mr. K. A. Clark is in charge of the testing and laboratory investigation.

During the past season a search for deposits of road stone and gravel was carried on in four areas: in Ontario, along the route of the Rideau Canal system, and between the towns of Port Hope and Napanee; in Quebec, in the counties of Argenteuil and Two Mountains north of the Ottawa river, and in Soulanges and Vaudreuil counties lying between the Ottawa and the St. Lawrence rivers.

The field work along the Rideau canal was done by the writer assisted by K. A. Clark. F. H. McCullough remapped the area from Port Hope to Trenton. The work from that town eastward to Napanee was in charge of K. A. Clark assisted by H. St. Denis and C. Williams. H. Gauthier directed the field work in the counties of Two Mountains and Argenteuil and was assisted by L. Clermont and O. Rolland. R. H. Picher investigated and mapped deposits of stone and gravel in the counties of Soulanges and Vaudreuil. The writer spent several weeks in the field in each of the three last mentioned areas supervising the work that was done and visiting nearly all of the more important deposits.

He is indebted to Professor M. B. Baker for the use of a geological map of and information on the area surrounding Kingston, prepared by him for the Ontario Bureau of Mines. The writer also wishes to thank his assistants for the painstaking method in which their work was performed.

Rideau Canal Route, Ontario.

About three weeks were spent in prospecting for deposits of first class macadam stone along the route of the Rideau Canal system between Kingston and Smiths Falls, Ontario. Scows drawing 4 to 5 feet of water with a capacity of about 175 tons can transport crushed stone from this area either to the front road at Kingston, or to the northern half of the proposed Ottawa-Prescott road which lies near the Rideau river. The object of the work was to locate stone of sufficiently good quality to justify its transportation by water and its use on the two roads mentioned. No time was, therefore, spent on deposits of stone which previous experience had given reason to believe would not be durable enough to stand very heavy traffic.

The Rideau Canal route from Kingston to Ottawa is about 135 miles in length. Outcrops of igneous and metamorphic rocks are found near the canal from a point 6 miles north of Kingston to a point about 13 miles southwest of Smiths Falls, and it is in this area that the work was done. Smiths Falls is about 29 miles by water from Becketts Landing where the Ottawa-Prescott road crosses the Rideau, and 64 miles from Ottawa. West of the Rideau Canal system between Kingston and Smiths Falls the topography consists of low hills rounded on top, in many cases steep-sided, and seldom over 100 feet in height. Among these hills lie many small lakes from which the canal system obtains its water supply. The highest part of the steamer channel is in Upper Rideau lake which is about 409 feet above sea-level and 42 miles from Kingston. From this lake southward the waters of the canal system drain to the St. Lawrence, and northward they drain through the Rideau lakes and river into the Ottawa. There are fourteen locks with a total drop of 165 feet on the St. Lawrence side and thirty-three with a total fall of 281 feet on the Ottawa River side of the divide.

The rocks outcropping on either side of the canal consist of crystalline limestone and other members of the Grenville series; coarse-grained igneous rocks which vary both in their composition and texture, with a foliated granite gneiss predominating; fine-grained metamorphic rocks with the appearance of meta-andesites; dykes of pegmatite, aplite, and diabase. In certain areas there are outcrops of Potsdam sandstones and of Beekmantown dolomites.

Deposits of stone of such quality as to justify their transportation for long distances for use in macadam construction were seen in one or two places only

along the route traversed. A number of diabase dykes, nearly all of them located by previous observers, were examined and a few deposits of a fine even-grained rock, which can for present purposes be referred to as meta-andesite and which laboratory tests indicate to be of first class quality, were examined. Some of the massive and foliated granites and schists outcropping near the canal could probably be used for local macadam work. The crystalline limestones and Potsdam sandstones should not be used in building road surfaces. The locations of diabase dykes at Kingston Mills, Findley station, Washborne locks, and 2 miles east of Cranberry lake in concession IX, were obtained from Professor Baker's map. A dyke mentioned by Vennor[1] lying between Adam lake and Noble bay on the west side of Lower Rideau lake, and one located by the writer on the west side of the steamer channel one mile south of the entrance to Seeley bay were also examined.

The largest of these dykes is that near Seeley bay. It outcrops in a 30-foot cliff along the side of the channel, but the main deposit lies about 200 feet north and 300 feet from the shore. The dyke varies in width from about 15 to 18 yards and the main deposit can be excavated to a depth of 15 yards without serious difficulty. By quarrying to water-level in the southern part and to a depth of 15 yards in the main deposit, 45,000 to 50,000 cubic yards of solid rock could be obtained at this place. The deposit lies about 25 miles by water from Kingston and there are seven locks in that part of the canal. The results of laboratory tests on a sample from this dyke are given on page 206.

All the other dykes examined near Kingston vary from a few feet to 17 feet in width except that at Washborne locks, which attains a width of 30 feet for a short distance. In none of these dykes is there more than a few thousand cubic yards in sight and the material will be difficult to quarry.

The dyke of "dolerite", mentioned by Vennor, on Lower Rideau lake, is said to outcrop at intervals for over one mile from the middle of lot 1 to the rear of lots 4 and 5, concession V, and from there, westerly to the front of lots 9 and 10, concession VI, North Burgess township. A careful search was made for diabase in this locality, but with unsatisfactory results. Near the house and barns of James Tully, close to Adam lake, the side of a diabase dyke is laid bare for a height of nearly 50 feet and a distance of over 200 feet. One hundred yards or more westward, the same dyke is 15 feet thick and dips 35 degrees to the north. Its strike is 85 degrees magnetic, that is slightly north of east. From the dyke near Tully's house about 10,000 tons of rock could be quarried and this would have to be hauled from one-half to one mile over a hilly road before it can be loaded for transportation by water. Other outcrops of a dark, fine-grained dyke of the same character were seen in positions which would indicate that they might be a part of the same body, but they were in all cases too narrow to be of commercial importance. Neither the amount of stone present in this locality nor its position in relation to navigable waters justifies its being quarried for other than local use.

A dyke of the same character on the farm of Philip White, north of Bass bay in Lower Rideau lake, is about 15 feet wide and lies on comparatively low ground, where quarrying would be difficult.

Two small hills of meta-andesite lie on the west shore of Opinicon lake south of Chaffey Locks and about one-half mile by wagon road from a station on the Canadian Northern railway. The water offshore is too shallow to consider direct transportation by water. There are about 10,000 cubic yards of rock in one hill and 5,000 in another nearby. It is tough and of good quality. See the results of tests on page 206.

The meta-andesite is the most promising deposit encountered.

[1] Vennor, Henry, G., "Explorations and surveys in the counties of Addington, Frontenac, Leeds, and Lanark", Geol. Surv., Can., Rept. of Prog., 1872–73, p. 169.

Road Materials Available for the Toronto-Montreal Road between Trenton and Napanee, Ontario.

(*K. A. Clark.*)

The road material survey for the Toronto-Montreal road, which was started in 1914, was continued during the summer of 1916. A report has been published dealing with the section from Toronto to Port Hope.[1] The area from Port Hope to Trenton was surveyed in 1914 and was remapped by F. H. McCullough during the past summer (1916).

The section covered this year extends from Trent river, west of Hastings county, eastward to Napanee river and to the east boundary line of Richmond township in the county of Lennox and Addington. This stretch was examined north of the Kingston road for a distance of 4 miles, and south of that highway to the shore of the bay of Quinte. All materials suitable for highway construction were examined and mapped and estimates were made of the quantities available.

TOPOGRAPHY.

In general, the country rises gently from the level of the bay of Quinte (245 feet above sea-level), northward at an average rate of 30 feet per mile. The bay shore is mostly low and swampy. Characteristic features of the topography are small rounded ridges, elongate-oval in plan, in most cases not more than 30 feet high, and trending in a northeasterly direction. These ridges become more frequent north of concession I. East of Salmon river, and especially in Richmond township, the country consists of broad flats and gentle slopes.

Four main streams flow through the area and empty into the bay of Quinte: they are Trent, Moira, Salmon, and Napanee rivers. It is noteworthy that, while Trent and Moira rivers, along with the smaller streams in the western section, flow in a southerly direction, Salmon and Napanee rivers and other small watercourses east of Belleville trend southwest through straight, almost parallel valleys. The rivers are rapid except along their lowest reaches where they are at lake-level. In concessions III and IV of Tyendinaga township, Salmon river flows through a ravine 100 to 150 feet deep.

GEOLOGY.

The bedrock, with the exception of two or three small Pre-Cambrian inliers, consists of limestones and shales of the Trenton formation. The rock for the most part is covered with drift.

Pre Cambrian schists and foliated granite gneisses outcrop near the Grand Trunk station at Shannonville and on the north bank of Salmon river northeast of Lonsdale in the form of small rounded hills surrounded by Palæozoic limestones. A good contact between the Pre-Cambrian and Trenton rocks was seen in a cut on the Canadian Pacific railway near the Grand Trunk station at Shannonville.

Beds of limestone and shale are exposed to some extent along the banks of Trent and Moira rivers. The main outcrops, however, occur at Point Anne and along the course of Salmon river. In Tyendinaga township, and especially in Richmond township, limestone beds come close to the surface in many places in ridges and under stretches of pasture land, although actual exposures of rock are few and of small extent.

[1] Reinecke, L., "Road materials along the north shore of lake Ontario between Port Hope and Hamilton," Geol. Surv., Can., Mem. 85, pt. V, 1916.

The limestone exposed along the banks of the Trent and Moira rivers is thin-bedded, and varies in texture from a fine to a coarse grain. Shaly partings separate many of the beds of limestone and shaly layers occur up to 4 feet in thickness. At Point Anne the beds are thicker and more massive. Three characteristic types persist through the strata in this section; a fine-grained, dark grey limestone with a light brown tinge; a coarse-grained, light grey limestone; and a dense, flinty, light grey limestone showing black wavy bituminous partings. There is practically no shale. Beds to a depth of 30 feet are exposed in the quarries of the Canada Cement Company, and of the Point Anne Quarries, Limited. The limestone outcropping along Salmon river is mostly massive and of the dark grey, fine-grained variety. North of the river the rock varies in texture from a fine to a coarse grain and is interbedded with a good deal of shale. Immediately east of Napanee a quarry is being worked which shows a face of about 35 feet of light brownish to drab grey, fine-grained to dense limestone. The rock is massive though parts of the face are thin-bedded. A little shale occurs near the floor of the quarry.

Sections of the boulder clay, which covers the larger part of the area, can be seen in places where gravel deposits accompanying the clay have been excavated. The boulder clay consists of fairly fresh, angular to rounded, boulders and pebbles, in a matrix of clay or rock flour which in this area is made up largely of ground up limestone.

A thin layer of bedded lake clay was observed in one or two places overlying gravel. An area of bedded blue clay overlain by an overburden of sandy soil occurs north of Point Anne on the Kingston road. The clay is being used by the Canada Cement Company.

Gravel deposits are scattered throughout the section from Trenton to Napanee. Much of the ridge land is gravelly, but the gravel lies in most cases in a very thin blanket over the boulder clay. Very few excavations with a depth of more than 5 feet of gravel were seen; and in most places the gravel layer is much thinner. This gravel is probably largely of glacial origin. Two pits located near the Kingston road and not far from the shore are in flat deposits which may have been formed by wave action.

A streak of sand extends from the shore east of Belleville northeastward across concession I.

ROAD MATERIAL.

Bedrock, field stone, and gravel constitute the materials in this area which can be used in road construction. Pre-Cambrian and Palæozoic types of bedrock are present; the Pre-Cambrian types on account of their foliated texture are unsuitable for road surfacing; some of the Palæozoic limestones on the other hand have been used with success in certain cases. Field stone is abundant from Trenton to the Salmon River valley in concessions II, III, and IV. Only a few patches occur in concession I, and there is very little east of Salmon river. Gravel is distributed fairly evenly over the whole area although good deposits are scarce.

There are no deposits of bedrock of any value west of Belleville. North of that town there is one small limestone quarry along the Madoc road and limestone can be obtained from the west bank of Moira iver not far from the town. The limestone here, however, is thin-bedded and considerable shale is present. On the south bank of Salmon river in lot 16, c ncession II, Tyendinaga township, a fine to medium-grained limestone is exposed in massive beds from 6 inches to 1 foot thick. Twelve feet of strata are exposed and the stone could be quarried along a wide face. It should compare well with the best stone in the vicinity. The

deposit is also near the main road. Rock can also be quarried on lot 25, concession III, Tyendinaga township. At that place 5 to 8 feet of fine-grained limestone becoming thinly-bedded toward the surface, is exposed in a face which extends some distance along the limit of a bare rocky area. None of the outcrops seen in Richmond township are very promising as quarrying prospects.

The best available limestone in the area is that being quarried at Point Anne and at Napanee. The beds at these quarries are massive and can be crushed to suitable sizes. Very little shale is present. The Point Anne Quarries Company, Limited, at Point Anne, are operating a plant capable of producing 800 tons of crushed stone per day. They have direct switching facilities with the Canadian Northern railway and can shunt cars onto the Grand Trunk and Canadian Pacific railways by way of the Canada Cement Company's tracks. The quarry is one mile south of the Kingston road. Crushed stone sells for from 55 to 60 cents per ton on the cars at the plant. The Napanee quarry is located on the Kingston road in a large limestone hill just east of the town. It is equipped with a portable crusher and screen. The proprietor, P. Bergin, supplies the town of Napanee with crushed stone for 50 cents per cubic yard. Laboratory tests indicate that the limestones of this area are only suitable for use on roads carrying light traffic, 100 vehicles or less, page 206.

Field stone is fairly plentifully distributed through all but the first concession of the townships from Trenton to the Salmon River valley. East of Salmon river there is very little field stone in the area surveyed. The bulk of the supply of field stone is unfortunately not situated close to the Toronto-Kingston road, which runs near the shore of the bay of Quinte through the first concessions. Between Trenton and Belleville, a distance of 9 miles, there are about 7,500 cubic yards of field stone up to one foot in diameter within 1½ miles of the Kingston road, and of this amount 4,000 cubic yards are located in the immediate vicinity of Trenton. There are about 30,000 cubic yards fairly evenly distributed within 1½ to 3 miles of the same stretch of road. Along the 6 miles from Belleville east to the Thurlow-Tyendinaga boundary line about 3,500 cubic yards occur within 1½ miles of the road and these are mostly within 1½ miles of the above-mentioned boundary line. There are 26,000 cubic yards within 1½ to 4 miles of this section of the road. Between the Thurlow-Tyendinaga boundary line and Shannonville, a distance of 1¼ miles, there are 2,400 cubic yards of field stone within 1 mile, and 3,500 cubic yards within 1 to 2 miles of the road. At Shannonville the Toronto-Kingston road crosses the Salmon river. With the exception of 2,000 cubic yards near Marysville, there is no field stone southeast of Salmon river and the deep river valley cuts off what supply there is to the north. The numbers given are for stone under 1 foot only. In general, about 30 per cent of the boulders are over 1 foot in diameter.

Throughout the area the field stone has been mostly thrown in a loose way along the fences. There are few fences containing large quantities of stone. The material under one foot in diameter consists of from 25 to 35 per cent coarse-grained granite boulders, 50 to 60 per cent limestone, and 10 per cent soft weathering boulders of both types. This is, of course, a very general statement. The larger boulders vary widely in composition, but the greater part of them are igneous rocks. Tests for percentage of wear were made on samples of boulder deposits from four localities in this area. The aggregates consisted of Trenton limestone and igneous rocks, the latter of varying durability. The material from each locality was divided into limestone and igneous rocks and tests run upon lots made up of 100 per cent limestone, 100 per cent igneous, and mixtures of the two in varying proportions. The wear of the wholly igneous aggregate was 3·4, 3·8, 4·4, and 5·8, and of the limestone 4·1, 6·7, 5·1, and 6·6, in each of the four localities respectively; the per cent of wear of a mixture of the two

lay between these values: thus at the locality where the 100 per cent igneous had a wear of 3·8 and the 100 per cent limestone 6·7 the per cent of wear of the mixtures came between 3·8 and 6·7. Field stone has been used around Belleville on the Kingston, Madoc, and Tweed roads. The surface of these roads has been cut up and destroyed in three years. Poor methods of construction and total lack of maintenance, however, are mostly responsible for this result. The county of Hastings has bought field stone, piled along the road, for $4 a cord.

Gravel, like field stone, is scarce along the Kingston road. One pit on lot 8, concession I, Sidney township, provides about the only supply between Trenton and Belleville. There is one deposit one mile north of the road on lots 26 and 27 and another just north of Belleville. Farther north, from 2 to 4 miles from the road there are nine deposits of gravel in which there are excavations. Between Belleville and Shannonville there is one deposit along the road in lot 16, concession I, Thurlow township. A deposit north of Belleville on lots 9 and 10, concession II, and a nearly exhausted pit half a mile north of the Grand Trunk station at Shannonville on lot 5, concession I, Tyendinaga township, constitute about the only other supply in this section. Two small deposits lie near the south bank of Salmon river 3 and 5 miles northeast of Shannonville, one at, and one about one mile north of the Toronto-Kingston road. Besides these there are three or four fairly good pits north of the Salmon river. South of the main highway, in the Indian reserve, there is a good gravel deposit lying on the old York road 3½ miles east of Shannonville and 2 miles from the Toronto-Kingston road. Between Marysville and Napanee there are four fairly good deposits close to the road.

The composition of the gravel remains very constant over the area. Eighty-five to 90 per cent of the pebbles are of fresh limestone and 10 to 15 per cent are of soft weathered material. There are few igneous pebbles. No further generalization can be made except that the proportions of gravel, sand, and boulders vary widely not only from pit to pit but also in places in the same deposit. Gravel for road work sells for 12 to 15 cents a cubic yard.

Gravel has been extensively used on the roads throughout the area. In Hastings county particularly, there are few roads on which there is an appreciable traffic that have not been gravelled. Where the traffic is light these roads are in very fair condition but the gravel does not wear well on the more frequented highways. Better results could be obtained from the use of this gravel if improved methods of construction were employed.

Road Materials in Two Mountains and the Southeastern Portion of Argenteuil Counties, Quebec.

(*H. Gauthier.*)

The work done during the past field season (1916) in this area is a continuation of a survey begun in 1915 on the materials available for the construction of a highway on the north side of Ottawa river between Hull and Montreal. The western half of the survey was completed in 1915.

The western boundary of the area surveyed during the past summer is 65 miles east of Hull; the southeastern corner is 12 miles west of Montreal and the eastern boundary extends in a northwesterly direction from there to the village of St. Jerome. This includes all of the county of Two Mountains and the greater part of Chatham and Argenteuil townships of Argenteuil county.

TOPOGRAPHY.

The area covered embraces all of a comparatively flat area south of the Laurentian plateau and extends from 2 to 4 miles into the plateau. The Laurentian plateau ends in a fairly abrupt escarpment facing to the south and rises to elevations of from 700 to 800 feet above sea-level within 4 miles of its front. The greater part of the plain lies between 125 and 250 feet above tide. An abrupt escarpment 75 feet high, extending east-west through the plain and from 3 to 5 miles south of the border of the Laurentian hills, marks the front of a clay terrace with hills of sand on it in places. North of Oka there is an irregular hill area rising to 700 feet and another smaller one at St. Andrews rising to 400 feet. The level of the waters of the Ottawa river falls from about 130 feet at the top of the Long Sault rapids at Grenville to 73 feet in lake of Two Mountains at Oka.

All of the area surveyed drains into the Ottawa river. The principal stream cutting through the area is river du Nord, a tributary of the Ottawa. A noteworthy feature of the drainage is the course of the latter river along a depression in front of the Laurentian escarpment. The river turns out of this depression at Lachute but other streams occupy it to the west.

Farming is extensively carried on in the plains section of Argenteuil and Two Mountains counties, and especially in the latter county where widely extended clay flats produce good crops of hay, oats, and potatoes. Apples are grown in the hilly country north of Oka and truck farming is carried on farther east. Four miles from Oka the Order of Trappists have an extensive agricultural establishment where, amongst other products the well-known brand of Oka cheese is made.

GEOLOGY.

Igneous and metamorphic rocks of Pre-Cambrian age outcrop in the Laurentian plateau and in hills at St. Andrews and north of Oka. The rocks consist of crystalline limestones, quartzites, granite and other gneisses, and anorthosites with very rare intrusions of bodies of unfoliated syenite porphyry and dark basic dykes. At Ste. Monique and in the hills near Oka alnoites geologically related to the rocks of the Monteregian hills have been intruded into the Pre-Cambrian. They are of Palæozoic age. The plain area is underlain by Palæozoic sediments comprising Potsdam sandstones, Beekmantown dolomite and calcareous sandstones, and Chazy limestones, shales, and sandstones. Over these lie boulder clays and blue marine clays and sands of the Glacial period. This drift cover is generally thick and outcrops are not plentiful over the plain.

ROAD MATERIALS.

Bedrock.

In the area surveyed there are three classes of stone suitable for road-making: igneous and metamorphic rocks, dolomites, and limestones.

Igneous and Metamorphic Rocks. Along the Laurentian Plateau front, in western Chatham township, the prevailing rock type is a pink syenite, while eastward near Brownsburg there are large areas of massive coarse rock of about the same character but with more quartz. This stone has been extensively quarried for building stone, paving blocks, and crushed stone. Probably the most durable macadam stone in Chatham township is a deposit of about 20,000 cubic yards of syenite porphyry in concession VI, north of Mabel post-office. It is a dense, dark bluish stone with phenocrysts of pink feldspar, breaks into sharp angular fragments, and is extremely tough and hard, page 206.

Farther east along the border of the Laurentian hills, the outcropping rocks are banded or foliated gneisses. Such stone from Hearst's quarry on the Brownsburg-Lachute road has been used in bituminous macadam work in the town of Lachute. It is a greenish grey, medium-grained rock, fairly massive, and of granitoid texture. The results of tests upon this stone are given on page 206 and indicate that it is fairly good road material.

All other classes of rock found north of Lachute are types to be rejected. They are altered sediments such as crystalline limestones and extremely foliated or schistose rocks. Farther east, the best stone to be found is some medium-grained, pink granite, moderately foliated and containing a comparatively large amount of quartz. This granite has been quarried for paving blocks north of St. Canute, page 206. There are also some outcrops of anorthosite in St. Columban, 2 miles north of river Du Nord, which may be of value as road material.

In the southern part of the area surveyed a small area of Pre-Cambrian rocks occurs east of St. Andrews, where small outcrops of much foliated granite gneisses and of crystalline limestones are found.

Several varieties of igneous and metamorphic rocks outcrop in the hills north of Oka. Of these, certain deposits of dark basic alnoites and diabases and light-coloured anorthosites may be considered the most promising for road purposes. One of the diabases lies on the east side of mount St. Alexis, but the amount of stone available is not over 5,000 cubic yards and it lies in narrow bodies which would be hard to develop. In the small hill about 1½ miles east of St. Benoit village about 2,000 cubic yards of the diabase can be quarried with less difficulty. The light-coloured anorthosite outcrops in large amount on the ridge one-half mile east of mount St. Alexis and in smaller quantity at the La Trappe monastery. East of St. Benoit there is a white, much altered rock which may be of the same character. The stone at La Trappe is apparently much better than at St. Benoit (page 206). There are large quantities available. There is a large outcrop of alnoite on Husereaus farm 4 miles north of Oka.

Dolomites. In certain localities in the flat country south of the Laurentian hills there are many outcrops of Beekmantown dolomite. Near the villages of Lachute, Ste. Scholastique, St. Augustin, St. Eustache, and in other places, this stone has been quarried for road metal and rough building stone. This material has given satisfactory results when used in water-bound macadam surfaces under light traffic conditions. Laboratory tests indicate that the fresh dolomites are tough and durable. The weathered dolomite is a much weaker stone.

Limestones. One mile southwest and 2½ miles west of St. Philippe d'Argenteuil there are two outcrops of bedrock resembling Chazy limestone. The limestone is not considered a very durable macadam stone (page 206), but similar stone has given good satisfaction in some localities under light traffic.

Boulder Deposits or Field Stone.

Extensive deposits of field stone occur in the southern portion of Chatham township extending from the Ottawa river 3 or 4 miles to the north, and from the western limit of the township eastward to St. Philippe. Within this area the stone is more plentiful on the high than on the low-lying land. The composition of the deposits varies: in the northern part they average 90 per cent durable stone, including rather tough igneous rocks; in the southern portion they average as much as 65 per cent soft shales and sandstones corresponding to the underlying bedrock; and in other places they average 40 per cent dolomites.

Farther east in Argenteuil township three belts of field stone lie between Ottawa river and Lachute. One of these belts lies near Ottawa river at the foot

of the hills east of St. Andrews, the second and larger of the two lies in the northern flanks of the same hills. About 3 miles to the north of this belt and 3 miles south of Lachute there is another area of field stone. The two southern areas carry up to 60 per cent of Potsdam sandstone. In the northerly deposit the stone in the fences varies greatly in their composition.

The main deposits of piled field stone in the county of Two Mountains are at St. Hermas station, along Côte St. Vincent, east and northeast of Ste. Scholastique, and in the neighbourhood of Grande-Frenière and St. Eustache. Smaller deposits lie in the hills north of Oka and elsewhere. South and southeast of Ste. Scholastique and in the neighbourhood of St. Eustache the field stone deposits carry about 80 per cent of dolomite boulders. The field stone in the Oka hills varies in composition, but elsewhere the deposits carry a great many Potsdam sandstone boulders. Along Côte St. Vincent at St. Hermas station, and directly east of Ste. Scholastique, parts of the deposits are made up nearly wholly of Potsdam sandstone.

Both laboratory tests and actual practice have shown that boulder deposits in this area carrying 75 per cent and over of igneous rocks or more than 75 per cent of dolomites give satisfactory service in water bound macadam roads under conditions of efficient construction and light traffic. The aggregates high in igneous stone are, however, the more durable. The deposits high in Potsdam sandstone, which are so common in Two Mountains county, are in places durable but do not cement well. Materials of which 50 per cent are sandstone boulders and the remainder of igneous rocks have made good roads under light traffic. Where the sandstone content was up to 80 per cent the road surfaces have not cemented well and have in places failed very rapidly.

Gravel.

While large deposits of fine yellow sand are of frequent occurrence through the district surveyed, gravel deposits are not plentiful. One large, rather sandy deposit northwest of Chatboro is the only occurrence of any importance in Chatham, although smaller deposits are met with. In Argenteuil township there are practically only two deposits. The more important one, owned by the Canadian Northern railway, lies immediately west of St. Andrews. The deposit is large and the gravel is of excellent quality. The other deposit, which is of smaller extent, lies in the East settlement of the parish of St. Jerusalem, 2½ miles northwest of St. Hermas.

Gravelly deposits carrying sand and soil or organic matter are commonly found in depressions between hills north of Oka. One of the best deposits of that kind lies north of St. Joseph du Lac. In the plain area of Two Mountains county there are no gravel deposits.

Road Materials in Soulanges and Vaudreuil Counties, Quebec.

(*R. H. Picher.*)

The counties of Soulanges and Vaudreuil occupy a triangular area stretching westwards from the junction of the Ottawa and St. Lawrence rivers to the boundary line of the province of Ontario. The village of Vaudreuil station, at its eastern extremity, is 24 miles, and rivière Beaudet, at the southwest corner, 44 miles west of Montreal. All of the county of Soulanges and the eastern and

southwestern portions of Vaudreuil were covered in the course of the summer. The route of the Montreal-Toronto highway will probably pass through Soulanges.

TOPOGRAPHY.

The main part of the area examined is a flat plain; in the northern part of Vaudreuil, however, there is a hilly tract which occupies about one-sixth of the area examined.

The greater part of the plain lies between 150 and 225 feet above sea-level. In general landslopes are very gentle, but the portion of the plain near the western boundary is slightly undulating. The hilly area lies to the south and southeast of Rigaud village and a mile or two from the Ottawa river. Directly south of Rigaud the elevated country rises in places fairly steeply, in others in a series of terraces to elevations of 700 feet above sea-level or about 500 feet above the surrounding plain. To the southeast and east across the valley of the Raquette are two broad benches ending in rather steep fronts to the northeast and south. The northern half of the area drains towards Ottawa river, and the southern into the St. Lawrence. The main streams emptying into the Ottawa are the Rigaud and Raquette rivers; Delisle and Rouge rivers drain into the St. Lawrence.

The level of the water in that part of the Ottawa river lying northeast of Vaudreuil county is about 73 feet. The level of the water of the St. Lawrence is over 150 feet above sea-level opposite rivière Beaudet and about 75 feet near the foot of the rapids at Cascades Point. A few miles below the junction of the two streams the water-level of lake St. Louis is 69 feet above tide.

In the plain where the top soil is clay the land is fertile: the sandy lands in the plain and in the higher benches are not so productive, and much of the hilly land south of Rigaud is still uncleared. Dairy farming is the chief industry.

GEOLOGY.

Outcrops of bedrock in this district consist of granites, syenites, and porphyries, subordinate gneisses of Pre-Cambrian age, and sandstones, shales, dolomites, and limestones of the Palæozoic.

The Pre-Cambrian outcrops in the hilly area south of Rigaud. The largest part of Rigaud mountain appears to be underlain by pinkish, holocrystalline alkalic granites and hornblende syenites. Intruded into this in the form of a thick sill is a porphyry with flesh-coloured feldspars in a brownish groundmass. This resembles quartz syenite porphyry found near Rawcliffe, north of Grenville. Foliation is practically absent from the rocks of Rigaud mountain. Across Raquette river to the southeast there are outcrops of well foliated, pink granite gneiss and of a hornblende-mica gneiss. One-half mile northwest of the station of Isle Cadieux and near the railway track bluish-black alnoite outcrops in a small hill. There are other small hills covered with large blocks of this stone which may have outcrops close under the surface, and 1½ miles southeast of St. Lazare there is a small hill covered with large blocks of granite gneiss.

No information was obtained regarding Palæozoic rocks in the northwestern part of Vaudreuil. In the area surveyed outcrops of Potsdam sandstones were seen at Hudson, on the shore of the Ottawa near Isle Cadieux, 1½ miles southwest of Vaudreuil station, and at Cascades Point.

The Potsdam, near Hudson, Isle Cadieux, and Vaudreuil station, is a brownish, feldspathic sandstone. At Cascades Point it is a white sandstone comparatively free from feldspar. The rock is as a whole very even grained; beds carrying pebbles up to pea size are seen in parts of the sections, and at Hudson there are

beds with quartz pebbles nearly 2 inches across. The sandstones lie nearly flat; they strike east of northeast and dip at low angles to the southeast, except near Vaudreuil where the dip is to the northwest.

Dolomites of the Beekmantown formation are found east of Côteau station near the St. Lawrence, and to the northwest of Ste. Justine de Newton on the Ontario line. The occurrence east of Côteau station consists of two outcrops in Delisle river and two quarries near the Soulanges canal. Near Ste. Justine there are two rather extensive outcrops. The dolomites are fine-grained, steel grey, and weather to a yellowish colour. A few thin beds of shaly dolomite are present. The beds lie nearly flat.

Flat-lying, dark brown limestone of the Black River formation outcrops in an old quarry northwest of Ste. Justine station.

Deposits of unconsolidated boulder clay, gravels, stratified clays, and sands of the Quaternary age overlie the rock to varying depths.

Hills of boulder clay and boulder sand occur near Hudson, in the northeastern part, and near St. Télesphore and Ste. Justine in the gently undulating country of the western portion of the area. Flat knolls of boulder clay of small extent, rising only a few feet over the level of the plain, are found near Vaudreuil station. Knolls of the same character are common south of St. Clet on the Canadian Pacific railway.

The boulder clay deposits are a mixture of silt and clay with angular pebbles of gravel size, and with varying amounts of boulders. The smaller pebbles seem to be made up largely of Potsdam sandstone, while the larger boulders generally carry a high percentage of the underlying rock. The boulder sand deposits are in most cases composed exclusively of sand and boulders with little or no gravel.

There are only two important deposits of gravel in the area examined. They lie at rivière Beaudet and at Ste. Justine de Newton. Areas of less importance are found west of St. Lazare and west of St. Télesphore. Along the western bank of Beaudet river is an isolated ridge of gravel, running approximately north and south. It is coarse and apparently unstratified; towards the north it consists of sand and boulders. One mile and a quarter north of the ridge, there are three small deposits of unstratified gravel included in a wide sand area. In a pit dug in the deposit, a zone of loam and intensely weathered gravel is found at the contact between the gravel and the stratified sand lying over it. A long interval evidently had elapsed between the deposition of the gravel and the laying down of the stratified sand. The gravel ridge of Ste. Justine is only a few feet deep; it is apparently a re-sorted gravel since it contains large numbers of broken marine shells. The deposits southwest of St. Lazare contain a large amount of sand. The other deposits are in most cases small pockets of gravel included in boulder clay and sand deposits.

Stratified blue clay covers all the eastern and southern portion of the area, and fills the depressions of the undulating country along the western boundary. It lies directly over the boulder clay.

A large deposit of stratified sand extends over the southern part of the county of Vaudreuil from Raquette river to the village of St. Lazare. In a section 10 feet deep where the road between the two counties crosses a creek, the sand is finely stratified and contains no marine fossil shells. Small iron ore deposits are found in several places in the sand area. In the southwestern part, a flat, stratified sand deposit covers a few square miles between St. Télesphore and rivière Beaudet.

ROAD MATERIALS.

Of the three classes of road materials found in this area the deposits of bed-rock are in most places of better quality than the glacial boulders or field stone overlying them. When the bed-rock is sandstone, however, this is not usually the case. The gravel deposits are not made up of very durable material.

Bedrock.

In the northeast part of the area examined there are two small hills of alnoite, 15 and 25 feet in height, from which fairly good macadam stone can be obtained, see the results of tests, page 206. They lie between Como and Isle Cadieux station on the Canadian Pacific railway. The alnoite is a dark, porphyritic rock in which mica crystals can be recognized with the naked eye. The stone is hard and tough under the hammer. Fracture planes are fairly regular through the rock and quarrying should present no great difficulties. Both deposits lie within half a mile of a good wagon road, and one is one-quarter of a mile from a railway siding.

The Beekmantown dolomite is more durable but does not cement as well as the alnoite. The dolomite outcrops in four different places between Côteau station and Côteau du Lac. It is a fine, even-grained, steel grey rock. Streets built of this stone in the village of Côteau du Lac in 1913 and 1914, were in good condition in 1916. The three exposures near Côteau du Lac will be difficult to develop. The average overburden to be removed runs from 5 to 8 feet in depth, and the permanent ground-water level is from 4 to 6 feet below the top of the rock. One of them has the advantage, however, of being close to a small wharf on the Soulanges canal by means of which stone can be supplied directly to more than 13 miles of the main road between Montreal and Toronto. The westerly of the four exposures is covered by overburden varying from 9 inches to 4 feet and the ground-water level is more than 7 feet below the top of the rock in places. It lies one-half mile from the Soulanges canal. The two deposits of dolomite lying northwest of Ste. Justine de Newton, along the boundary line of the province of Ontario, are of fairly tough stone. Both lie in ridges about 8 yards in height and the overburden is not thick. The stone is from 16 to 18 miles from the St. Lawrence.

In the same part of the area, one-half mile northwest of Ste. Justine station, is a small outcrop of Black River limestone. There is not much stone available and it is rather soft.

The outcrops of Potsdam sandstone in the eastern part of the area are of poorer quality than the dolomite or gabbro. The sandstone outcrops near the village of Hudson and has been used locally on the Hudson and Vaudreuil road with unsatisfactory results. Large quantities are available near Isle Cadieux and at Cascades Point, and a small quantity southwest of Vaudreuil station.

The area on Rigaud mountain was prospected but not completely surveyed. There are three large deposits of a very durable, brownish syenite porphyry (see the results of tests on page 206. One lies on top of the high point overlooking Rigaud village at the northwestern edge of the mountain. It should be possible to develop the syenite porphyry from the steep cliffs on that side of the mountain. The two other deposits lie just north of the St. Georges road on both sides of a creek valley about one mile west of the Geodetic Survey tower. Millions of tons of porphyry can be obtained from these three deposits. Medium-grained pink granite outcrops between this deposit and the road and is quarried for paving blocks on the steep mountain slope. The pinkish, somewhat porphyritic granite at the shrine of Notre Dame de Lourdes is of the same kind. The granite is fairly durable but not as good as the porphyry.

Boulder Deposits or Field Stone.

Isolated patches of field stone lie near Ottawa river in the northeastern part of Vaudreuil county, but the largest area covered with boulders is along the western boundary where there is a large quantity of stone to be had. Most of the deposits carry a high percentage of Potsdam sandstone. They have been extensively used in water-bound macadam work near Ottawa river near and west of Vaudreuil village. Here, just as in Two Mountains county, aggregates carrying up to about 50 per cent Potsdam sandstone, with the remainder of igneous rocks, have given satisfactory service for a few years in places where the construction was well done, the maintenance poor, and the traffic light or moderate in volume. Where the percentage of Potsdam sandstone was very high the roads have not lasted as well.

The distance of the front road to the nearest of the large deposits on the west boundary is about 8 miles. Most of the stone, however, is close to some local road.

Gravel.

Two gravel areas of some size are found along the western edge of the area, one at rivière Beaudet, the other near Ste. Justine de Newton. Other minor areas occur along the western boundary. There is also one on the sand plateau southwest of St. Lazare and another at Pont Château on Rouge river.

The gravel of rivière Beaudet lies in a long ridge crossing the river road and the railway. To the north of the railway it is bouldery in places and sandy in others; to the south there is more material of gravel size. About 30 per cent of the pebbles are of some soft material. There is a large amount available near the main Montreal-Toronto road. The material should be screened before using.

In the village of Ste. Justine de Newton there is a ridge of fine gravel, from 6 to 10 feet in depth. It is of rather poor quality, and lies about 15 miles from the main road. The gravels at St. Lazare are very sandy and the deposit at Pont Château is quite small.

Laboratory Tests of Bedrock.

The results of laboratory tests upon samples of bedrock collected during the season of 1916 are given in the table below. The more important tests are for resistance to abrasion expressed in percentage of wear, resistance to impact expressed in toughness, and cementing value. The cementing value was not satisfactorily determined and has been omitted from the table. The relation between the laboratory results and the value of the stone under service conditions is indicated by a recommendation of the American Society of Civil Engineers, January, 1917, that stone used in a water-bound broken stone road shall have a percentage of wear of not more than 5 and a toughness value of not less than 6. Specifications adopted by the American Society of Municipal Improvements in 1914 require that stone used in a broken stone road with bituminous surface shall have a per cent of wear of not more than 3·63 and a toughness of not less than 13. A cementing value of less than 25 is considered very low for water-bound macadam construction.

RESULTS OF TESTS MADE UPON BEDROCK.

Rideau Lakes, Ontario.

Locality	Rock species.	Age or formation.	Physical properties.					
			Per cent of wear	French co-efficient of wear.	Toughness.	Hardness.	Specific gravity.	Absorption in lbs. per cu. ft.
Seeley bay	Diabase	Pre-Cambrian	2·3	17·4	9	18·7	3·05	0·1
West shore Opinicon lake ½ mile southwest of Chaffey Locks	Meta-andesite	Pre-Cambrian	2·3	17·4	21	17·7	2·84	0·2
Trenton to Napanee, Ontario.								
Bleekers quarry, north Belleville	Limestone with shale	Trenton	5·0	8·0	8	15·2	2·72	0·2
Pt. Anne, bed a	Limestone	Trenton	3·3	12·1	7	14·3	2·70	0·4
Pt. Anne, bed b[1]	Limestone	Trenton	5·2	7·7	5	10·8	2·70	0·5
Pt. Anne, bed c	Limestone	Trenton	3·3	12·1	6	15·2	2·70	0·1
Pt. Anne, bed e	Limestone	Trenton	4·0	10·0	7	15·3	2·73	0·3
South bank of Salmon river 4 miles northwest Shannonville	Limestone	Trenton	6·9	5·8	4	13·2	2·72	0·5
Napanee	Limestone	Trenton	4·9	8·2	7	15·5	2·71	0·1
Two Mountains and Southeast Argenteuil, Quebec.								
Two miles east of Rawcliffe, Chatham township	Syenite porphyry	Pre-Cambrian	2·0	20·0	38	19·2	2·70	0·8
Hearst's quarry, northwest of Lachute	Granite gneiss	Pre-Cambrian	2·2	18·2	13	18·5	2·75	0·2
Laurentian Granite Co., Brownsburg	Coarse-gr.granite		4·0	10·0	9	18·8	2·64	0·5
Argenteuil Granite Co., Brownsburg	Coarse-gr.granite		3·8	10·5	9	18·8	2·64	0·6
Premier Granite & Sand Co., St. Canute	Granite gneiss		2·3	17·4	12	18·6	....	...
Southeast of La Trappe, Oka	Anorthosite	Pre-Cambrian	2·6	15·4	13	18·6	2·66	0·5
East of St. Benoit	Anorthosite	Pre-Cambrian	6·0	6·7	9	....	2·75	0·4
Husereaus farm, Ste. Germaine Rd. north of Oka	Alnoite	Palæozoic	3·4	11·8	12	18·2	3·26	0·8
One-half mile north of Ste. Monique	Alnoite	Palæozoic	2·9	13·8	16	17·6	3·15	0·1
East of St. Benoit	Diabase	?	2·74	14·6	23	18·6	3·02	0·9
Mt. St. Alexis north of Oka	Diabase	?	2·6	15·4	18	18·2	2·91	0·3
Smith's quarry, 1 mile southwest of St. Philippe	Limestone	Chazy	4·4	9·1	6	15·7	2·73	0·3
Binette's quarry, St. Augustin	Dolomite	Beekmantown	3·8	10·6	17	15·9	2·80	0·3
Thompson's quarry, N. of Belle Rivière	Dolomite and magn. limestone	Beekmantown	5·3	7·5	20	15·8	2·76	0·5
Gratton's quarry, 2½ miles east of St. Hermas station	Dolomite and magnesian limestone	Beekmantown	2·8	14·3	17	16·7	2·82	0·1
Col. Smith's quarry, St. Jerusalem road, Lachute	Dolomite	Beekmantown	3·9	10·3	11	14·5	2·86	0·5
McOuat's quarry, Lachute	Dolomite	Beekmantown	3·0	13·3	17	17·1	2·79	0·5
Near Ottawa river, Cushing	Dolomite	Beekmantown	3·5	11·4	13	16·7	2·94	2·0
Fraser's quarry, Lachute	Dolomite	Beekmantown	3·2	12·5	16	15·9	2·84	0·7
Côte des Anges, Ste. Scholastique	Calcareous sandstone	Beekmantown	5·9	6·8	..	....	....	...
Soulanges and Vaudreuil Counties, Quebec.								
West of Isle Cadieux station	Alnoite	Palæozoic	4·4	9·2	13	17·4	3·23	0·9
One and one-half miles southeast of St. Lazare	Medium-grained pink granite	Pre-Cambrian	3·6	11·0	13	18·8	2·71	0·5
Dempsey's quarry, Coteau Jct	Dolomite	Beekmantown	3·5	11·4	17	16·3	2·84	1·0
Bédard's quarry, Ste. Justine	Dolomite	Beekmantown	2·75	14·8	15	16·9	2·80	0·5
At foot mountain, 1 mile west of Rigaud	Granite	Pre-Cambrian	2·6	15·4	13	18·7	2·63	1·0
Ste. George range, Rigaud mountain	Syenite porphyry	Pre-Cambrian	2·3	17·5	18	18·9	2·73	0·5

[1]Beds a, b, c, e were sampled from the same vertical face of limestone at Point Anne; a at the bottom is 6 feet; b, 3 feet; c, 3 feet; d resembling c, 6 feet; e, 6 feet; and f on top 5 feet thick.

MOLYBDENITE DEPOSITS OF THE MOSS MINE, QUYON, QUEBEC.

(*Charles Camsell.*)

The Moss mine is situated 3 miles north of the station of Quyon on the Canadian Pacific railway between Ottawa and Waltham. A good road over which a load of 2 tons can be drawn with a single team of horses, connects the mine with the railway.

The company operating the mine owns 250 acres of mining lands in this vicinity. The mine lies on a bench at the foot of the high Laurentian escarpment that overlooks the valley of Ottawa river. The surface of the bench is covered with a thick deposit of sand and gravel through which, however, a number of low rounded knobs of granite project. The drift-covered portion of the bench was at one time cultivated but is now pasture, while about the rocky knobs are clumps of spruce and pine timber. About 300 yards north of the mine the Laurentian escarpment rises as a rocky, broken slope to a height of several hundred feet above the valley.

Active mining of molybdenite ore was begun in the early spring of this year (1916), and has proceeded steadily ever since. A force of about 80 men was employed most of the summer, part in mining and part in the erection of a concentrating mill and other mine buildings. At the time of examination at the end of June, 1916, a considerable quantity of ore had already been shipped from the mine, some to Denver, Colorado, and some to Ottawa.

The ore is mined from an open pit 100 feet long and 40 feet wide and is afterwards hand cobbed and sacked for shipment in wagons to the railway station. Three grades of ore are produced, the high grade running 5 to 6 per cent molybdenite has been shipped to Denver, a medium grade goes to Ottawa, and a low grade is held for treatment in the mill when completed. A concentrating mill is in course of erection which it is stated will be capable of treating 100 tons of ore per day.

The country rock of the mine is a fine-grained, pink, hornblende granite, which appears to have intruded an older, coarse-grained, grey granite, inclusions of which are scattered through it. The pink granite is cut by both pegmatite and aplite veins along which some alteration has taken place.

The principal ore-body, known as the No. 1 mine, outcrops in a low, elongated ridge of granite surrounded on all sides by drift and rising only a few feet above it. The ore-body has a width of 40 to 45 feet and is bounded on both sides by granite. It cuts across the ridge with a length of 100 feet exposed and passes at either end under the drift. The ore is a somewhat coarse-grained mixture of quartz, feldspar, pyroxene, fluorite, pyrite, pyrrhotite, and molybdenite. It is, however, extremely variable in the relative proportions of its constituent minerals. The proportion of molybdenite varies in hand specimens from 1 to about 7 per cent and occurs in flakes disseminated through the gangue. As the ore-body has no sharply defined walls, and molybdenite occurs not only in the ore-body itself but to a limited extent in the pink granite which borders it, it has been difficult to determine the relationship of the ore-body to the granite.

It was at first supposed that the ore-body was originally a block of limestone detached from a larger body of limestone and completely metamorphosed and mineralized by the pink granite in the course of intrusion. Later examination of a suite of thin sections, however, seemed to show that the ore-body is more probably a pegmatite cutting through the granite. The true interpretation of the origin of the ore deposit is important and has an important bearing on the life of the mine; for if the latter interpretation is correct the ore is likely to persist to greater depth than if the first interpretation proves to be correct.

Flakes of molybdenite occur in the granite 100 feet or more on either side of the ore-body. These suggest that the molybdenite is an original constituent of the pink granite, but it by no means follows that the mineral will be found concentrated in such quantity in that formation as to form ore of molybdenite. The aplite and pegmatite phases of the granite are the only likely sources of ore.

A second deposit of molybdenite, known as the No. 2 mine, is situated on the slope of the escarpment about 2,500 feet in a direction north 30 degrees east from the No. 1 mine.

The country rock there is the same fine-grained, pink granite with a massive jointed structure. It is cut by a number of small aplite and pegmatite veins which strike diagonally up the slope of the hill. Both are mineralized to such an extent by molybdenite as to constitute ore of that mineral. The molybdenite is disseminated through the aplite veins in very fine flakes, while the pegmatites contain molybdenite in somewhat larger flakes.

It is difficult in the present state of development of No. 2 mine to give any opinion as to its future, but a continuous supply of ore is likely to be very uncertain, both because of the irregular distribution of the molybdenite through the rock, and the lack of strength and continuity of the aplite and pegmatite veins.

GRENVILLE DISTRICT, ARGENTEUIL COUNTY.—PART OF AMHERST TOWNSHIP, LABELLE COUNTY, QUEBEC.

(*M. E. Wilson.*)

INTRODUCTION.

The greater part of the field season of 1916 was spent by the writer in making an examination of the geology and mineral resources of an area approximately 150 square miles in extent, situated to the north of the Ottawa river in the vicinity of the town of Grenville, Argenteuil county, Quebec. Data necessary for the preparation of a geological map of the area were procured and in addition special detailed maps of areas in the vicinity of the principal magnesite deposits of the area were prepared. (See maps, Nos. 1674 and 1675.)

At the close of the field season two weeks were spent in mapping the geology of an area approximately 20 square miles in extent in the vicinity of deposits of kaolin (china clay) and graphite in Amherst township near the western terminus of the Huberdeau branch of the Canadian Northern railway.

The writer wishes to express his indebtedness to Mr. W. P. Boshart of Ottawa, Mr. J. C. Broderick, managing director of the Canadian China Clay Company, Mr. Gamble, manager of the North American Magnesite Company, Mr. A. Lannigan of Calumet, Mr. Roseburgh, manager of the Scottish Canadian Magnesite Company, and to many others who by their courteous interest assisted in the progress of the work.

The writer was assisted in the geological field work by Victor Dolmage and in the surveys and other duties by Messrs. E. Giguère, G. M. Demers, and L. P. Gouin, all of whom performed their work in a satisfactory manner.

Grenville District, Argenteuil County, Quebec.

GENERAL GEOLOGY.

General Statement.

The rocks occurring in the Grenville district, when classified in a general way according to their age and structure, fall into four definite groups:

(1) A basal group of Pre-Cambrian rocks which have all been more or less deformed and metamorphosed.
(2) Intrusive igneous rocks of late Pre-Cambrian age.
(3) Approximately flat-lying sandstone, shale, and sandstone of early Palæozoic age.
(4) Unconsolidated gravel, sand, and clay of Pleistocene and Recent age.

Arranged in tabular form the succession of formations in the district in detail is as follows:

Table of Formations.

Quaternary	Champlain	Marine clay and sand.
	Glacial	Boulder clay, gravel, and sand.
Palæozoic	Chazy	Sandstone, shale, and limestone.
	Beekmantown	Limestone.
	Potsdam	Sandstone.
Late Pre-Cambrian		Granite, quartz syenite, syenite. Diabase.
Early Pre-Cambrian		Granite-syenite gneiss. Metamorphic pyroxenite.
	Buckingham (igneous) series	Pyroxene syenite, pyroxene diorite, pyroxene gabbro.
	Grenville series	Quartzite, garnet-sillimanite gneiss, crystalline limestone.

Basal Complex.

General Statement. The oldest of the four great groups into which the rocks of the Grenville district have been subdivided—the basal complex—is composed of a heterogeneous assemblage of sedimentary and igneous rocks which, while not all contemporaneous in age, have all been partially or completely transformed to a crystalline or foliated condition as a result of the regional metamorphism to which they have been subjected. In this respect they are in striking contrast with the rocks that succeed them in that the latter are not metamorphosed and retain all the characteristics by which they were originally distinguished. If classified on the basis of age only, the rocks of the complex must be regarded as b elonging to only three groups: (1) a group of recrystallized marine sediments constituting the Grenville series; (2) a group of igneous pyroxenic rocks of intermediate composition intruding the rocks of group 1—the Buckingham seri es; and (3) batholithic masses of granite gneiss and syenite gneiss intrusive into the rocks of both 1 and 2; but the metamorphic action of the pyroxene gneisses of group 2 on the limestone member of the Grenville series has transformed considerable masses of this rock into diopside and related minerals forming a fourth common rock type generally known as "pyroxenite."

The rocks of the Grenville series being generally less resistant to erosive agencies, are usually found to underlie the valleys of the district whereas the granite and syenite gneisses which are less easily eroded, form all the prominent hills.

Grenville Series. The oldest rocks recognized to be present in the Grenville district belong to what is generally known as the Grenville series. It is believed that the rocks of this series were originally laid down as alternating beds of shale, sandstone, and limestone, but, owing to the intense metamorphism to which they have been subjected, the shale has been recrystallized to sillimanite-garnet gneiss, the sandstone to vitreous quartz, and the limestone to crystalline limestone. The reasons for this conclusion are the following: (1) chemicai analyses of the

sillimanite-garnet gneiss member of the series show that this rock has in every detail the chemical composition of a shale and thus the three rock types, sillimanite-garnet gneiss, quartzite, and crystalline limestone have respectively the composition of the three dominant members of marine sedimentary series of the well sorted types, and (2) these rocks occur interstratified with one another in a manner similar in every respect to the way normal marine sedimentary deposits usually occur.

Buckingham Series. The Buckingham series is a group of igneous pyroxenic rocks found widely distributed throughout the Pre-Cambrian of southern Quebec and eastern Ontario. In the district where the series was originally described members of the series occur ranging in composition from pyroxene granite to peridotite, but in the Grenville district only pyroxene syenite, pyroxene diorite, pyroxene gabbro, and pyroxenite were observed. These have been intruded into the Grenville series, partly as thin bands injected between the beds or along the planes of foliation and partly as large lenticular bosses. Since their intrusion they have been subjected to intense deformation and are generally more or less foliated, the gneissoid structure being especially well developed in the thin *lit par lit* injections.

Metamorphic Pyroxenite. The rocks of this class generally occur as irregular discontinuous masses or bands, elongated in the direction of the strike of the garnet gneiss, quartzite, limestone, pyroxenic gneisses, and other rocks with which they are associated. The pyroxenite in its most typical occurrences is mainly composed of a pale green to white massive or granular pyroxene having approximately the composition of diopside, throughout which red or blue microcline commonly occurs as scattered crystals or in pegmatitic masses. With the pyroxene are associated a great variety of other minerals of which the following are the most common: scapolite, calcite, phlogopite, apatite, tourmaline, green amphibole, pyrite, chalcopyrite, titanite, fluorite, quartz, and prehnite. These minerals occur as scattered individuals, as encrustations on the walls of geodal cavities, embedded in calcite and in irregular veins. From the study of the character and relationships of the pyroxenite in the Grenville and other districts it has been concluded that this rock is a secondary type formed from the crystalline limestone of the Grenville series by the action of pegmatitic solutions derived from the intrusives of the Buckingham series.

Granite-syenite Gneiss. The granite gneiss and syenite gneiss composing the third member of the basement complex are the most widespread of all the rocks found in the district, occurring as enormous batholiths and small masses and bands which have intruded their way through the rocks of the Grenville and Buckingham series. Lithologically, the granite gneiss and syenite gneiss are pink to grey rocks consisting of granular feldspar or granular feldspar and quartz with biotite or hornblende or biotite and hornblende together as the ferromagnesian constituents. In places the rocks of this group are fine-grained and aplitic in appearance whereas in other localities they are exceedingly coarse and porphyritic throughout wide areas.

The relationships of the masses of granite and syenite gneiss to the older rocks into which they were intruded seem to indicate that these masses made room for themselves in two principal ways: (1) by thrusting aside the older rocks and (2) by *lit par lit* injection. That the batholiths made room for themselves in part, in the first manner, is indicated (1) by the distribution of the older rocks in the form of belts and scalloped-shaped areas intervening between the batholiths and (2) by the manner in which the bedding, banding, and foliation in the intruded rocks tend to parallel the batholithic margin. This parallelism is especially well developed in the easily deformed limestone member of the Grenville series. The second mode of intrusion was evidently a widespread phenomenon

for, throughout the larger part of the batholithic masses of granite and syenite, there are numerous included bands of garnet gneiss, quartzite, and pyroxenic gneiss ranging in width from a fraction of an inch to several hundred feet and penetrated by numerous transverse dykes emanating from the adjoining granite and syenite.

Late Pre-Cambrian Intrusives.

General Statement. The rocks occurring in the Grenville district, which have been classed as late Pre-Cambrian, are igneous intrusions which are lithologically different from the rocks of the basement complex and, unlike the rocks of the basement complex have not been greatly deformed or otherwise metamorphosed. On the other hand, no rocks of similar character have been observed to intrude the Palæozoic sediments which overlie the Pre-Cambrian in the southern part of the district. It is probable, therefore, that these intrusives are not only considerably younger in age than the basement complex but also are older than the Palæozoic and are, therefore, late Pre-Cambrian in age. They include two separate types of intrusives: (1) diabase dykes, and (2) a single stock-like mass of granite, quartz syenite, syenite, and quartz syenite porphyry.

Diabase. The rocks of this class occur as numerous approximately east-west trending dykes of diabase ranging from less than a foot to several hundred feet in width. These form part of a widely extended dyke system which parallels the southern margin of the Laurentian plateau for a distance of at least 150 miles in this region. The diabase is a typical, fine-grained to coarse variety consisting of labradorite, augite, and scattered grains of ilmenite.

Granite, Quartz Syenite, Syenite, and Quartz Syenite Porphyry. Extending along the margin of the Laurentian plateau to the northeast of the town of Grenville there is an elliptical mass of rock approximately 8 miles in length and 5 miles in width, which has been intruded abruptly across the rocks of the basement complex, and which for the purpose of description may be designated the Grenville stock. In composition, the mass consists in the main of grey to pink, medium-grained feldspar and dark green hornblende with varying porportions of quartz, so that all intermediate types between a granite and a syenite are present, although on the whole the granite is most abundant. Within the granite and syenite there are also numerous masses of fine-grained, dark grey to pink aphanitic quartz syenite porphyry. The relationships of these masses in places is somewhat obscure but at other points they are cut across by numerous dykes of the granite-syenite indicating that in part, at least, they are included blocks and older in age than the granite-syenite.

While the Grenville stock is not found in actual contact with either the diabase dykes or the Palæozoic sediments occurring in the district it is probable, as was concluded by Sir William Logan, who studied the mass in 1853, that it is younger than the former and older than the latter, for the diabase dykes although abundant throughout other portions of the region have nowhere been observed to penetrate the stock; on the other hand no dykes similar in composition to the granite syenite of the stock have been observed to intrude the Palæozoic sediments which outcrop in close proximity to the stock on the south. It would seem probable, therefore, that the Grenville stock is very late Pre-Cambrian in age.

Palæozoic.

That portion of the Grenville district which lies adjacent to the Ottawa river and south of the Laurentian escarpment is underlain by approximately flat-lying beds of Palæozoic shale, sandstone, and limestone which protrude here and there as ledges in the stream bottoms or as low east-west trending escarp-

ments. The formations represented by these sediments named in ascending order include the Potsdam, the Beekmantown, and the Chazy.

Pleistocene.

Glacial. In common with the whole territory formerly covered by the Labradorean continental glaciers, the bedrock surface of this region is covered by an irregular mantle of glacial debris. This consists in the main of scattered boulders and irregular knobs and ridges of gravel and sand, in many portions of which deep undrained depressions occur.

Marine Clay and Sand. Throughout all the lower portions of the Grenville district the Glacial and older formations are overlain by stratified clay and sand containing marine shells and form extensive flats in the depressions within the Laurentian plateau up to elevations of 735[1] feet above sea-level. The character of these deposits varies considerably from point to point, but in the main, the clay beds predominate at the bottom and the sand at the top. In the vicinity of the Ottawa river, the latter occurs in extensive areas, in places with a typical desert-like duned surface.

MINERAL DEPOSITS.

The principal minerals of commercial value found in the Grenville district are magnesite, amber mica, graphite, and magnetite. Of these, magnesite is especially important, 55,413 tons of the material valued at $563,829 having been shipped from the district in 1916.

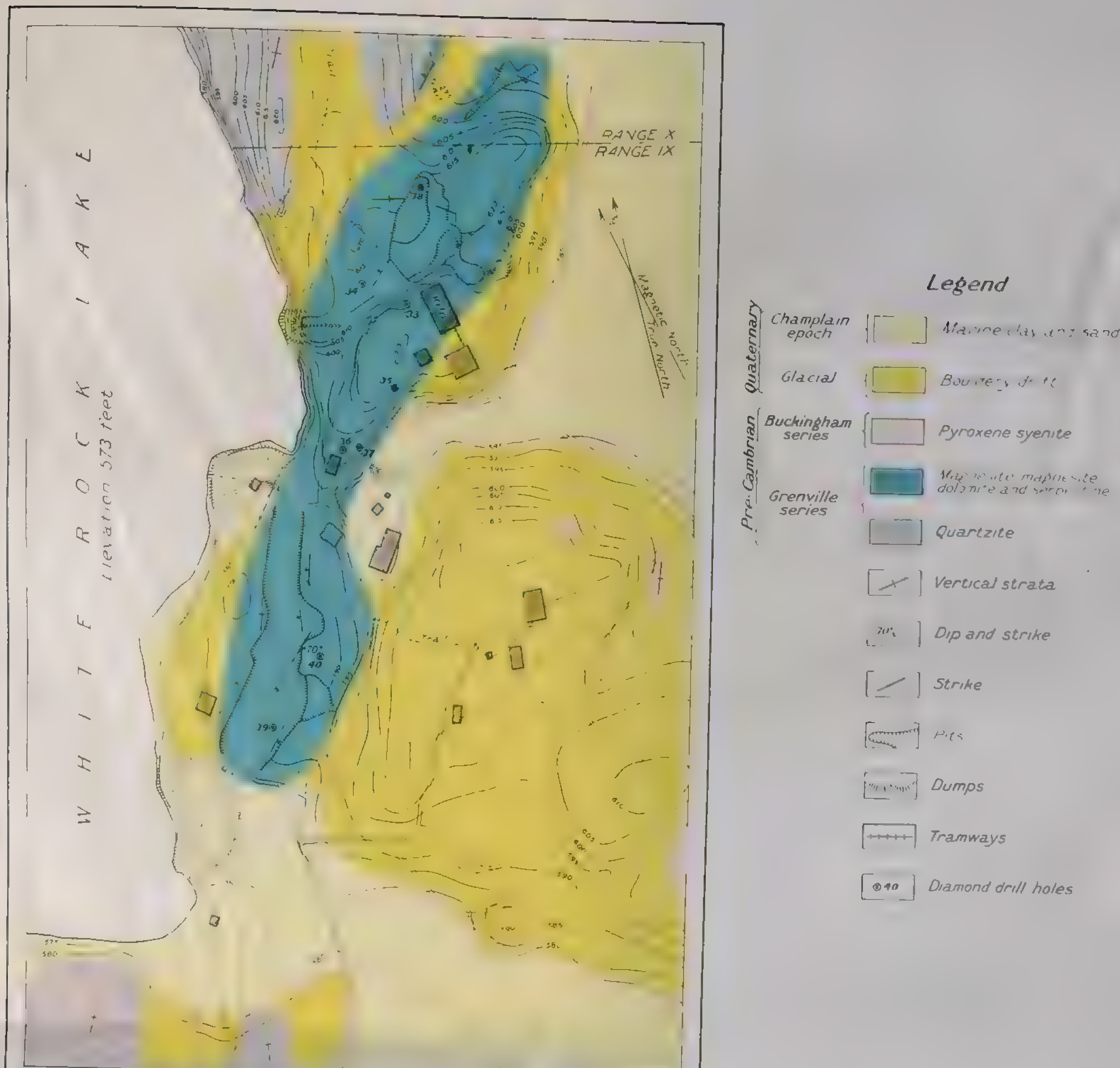
Magnesite Deposits.

Distribution and Geological Relationships. The deposits of magnesite so far discovered in the Grenville district are found in four principal localities: the north end of lot 15, range IX, the south end of lot 15, range XI, and the north end of lot 18, range XI, in Grenville township; and lot 13, range I, in Harrington township.

At all of these points, the magnesite occurs associated with serpentine, dolomite, and other minerals in lenticular outcrops protruding through the marine clay and sand, which, in this district, as everywhere in the Laurentian highlands adjoining the lower Ottawa and lower St. Lawrence, occupies the bottoms of the major valleys. On lot 15, range IX, Grenville township, the magnesite deposit is adjoined on the west by Grenville quartzite, while on the east at a distance of about 400 feet outcrops of pyroxenic syenite belonging to the Buckingham series occur. On lot 15, range XI, Grenville township, the conditions are very similar to those on lot 15, range IX, Grenville, quartzite occurring on the west and pyroxenic gneiss to the east, but between the pyroxenic gneiss and the magnesite several outcrops of metamorphic pyroxenite are present. On the Shaw property, lot 18, range XI, Grenville township, garnet gneiss belonging to the Grenville series occurs to the east of the deposit, metamorphic pyroxenite to the south, and crystalline limestone to the northwest. On lot 13, range I, Harrington township, the adjoining outcrops consist of pyroxenic gneiss, crystalline limestone, an[illegible] net gneiss. In general, therefore, it may be said that the magnesite in all [illegible] occurrences is found in association with the metamorphosed group of sedi[illegible] crystalline limestone, garnet gneiss, and quartzite, composing the Gr[illegible] series, and that in three localities it is found in close proximity to outcr[illegible] the pyroxenic rocks of the Buckingham series.

General Character of Deposits. The magnesite found in the Grenville district is a glistening cream white to milk white or grey material, occurring in

[1] According to elevations on Hawkesbury sheet published by the Department of Militia and Defence.



Geological Survey Canada Catalogue No 1674

Diagram showing magnesite deposits,
Lots 15, ranges IX and X, Grenville township, Argenteuil county, Quebec.

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To accompany Summary Report by M E Wilson, 1916.

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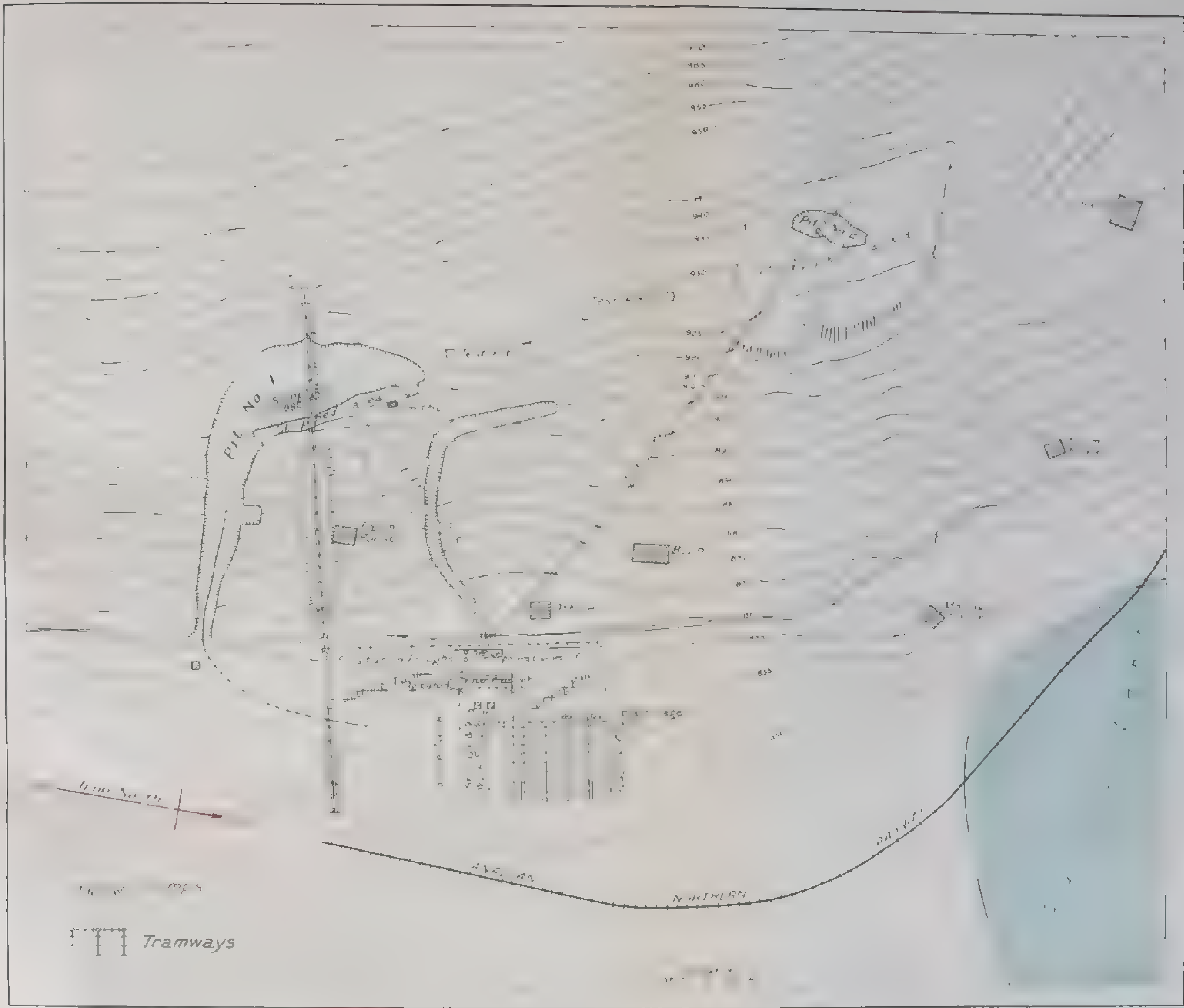


Geological Survey, Canada

Diagram showing pits in kaolin deposits in
lots 5 and 6, range VI south, Amherst township, Labelle county, Quebec

Scale of Feet

To accompany Summary Report by M E Wilson, 1916

extensive masses associated with bands or lenses of dark green to light yellow serpentine. Serpentine also occurs disseminated in the magnesite in places and the magnesite nearly everywhere contains more or less included dolomite. Moreover, since dolomite ($CaMgC_2O_6$) contains 30 per cent lime, the magnesite generally contains a certain amount of this constituent, the percentage present varying in proportion to the amount of dolomite which the magnesite contains. In a few localities the dolomite included in the magnesite is more coarsely crystallized, and is whiter in colour than the surrounding material, and can be distinguished in this way; but, throughout the great mass of the deposits the magnesite and dolomite are so similar in appearance that the presence of the dolomite is difficult to detect.

The intimate manner in which the dolomite is disseminated through the magnesite is made evident in several ways. Where a magnesite outcrop has been exposed to atmospheric agencies, the dolomite, being more soluble than the magnesite, dissolves away more readily, so that the weathered surface presents an irregular pitted appearance, the magnesite forming the prominences and the dolomite occupying the depressions. The presence of the dolomite in the magnesite can also be detected by treating the mixture with cold strong hydrochloric acid, effervescence occurring where the dolomite is present. The relationship of the dolomite to the magnesite can best be observed in the material after it has been calcined in a kiln or furnace without access of air (deoxidizing atmosphere) the dolomite assuming a white and the magnesite a pink colour as a result of this operation.

Structure of Magnesite Deposits. In highly crystalline metamorphosed rocks, such as comprise the Grenville magnesite deposits, structural features are not everywhere apparent, but, in some of the deposits, parallel planes of parting, banding, and other features are conspicuously exhibited. The outcrops in which the magnesite is found are all elongated in a direction approximately parallel to the trend of the bedding in the quartzite and garnet gneiss belonging to the Grenville series, which outcrop in the vicinity of the deposits; likewise, within the deposit the elongation of the masses of serpentine, the strike of the planes of parting, and the banding which commonly characterizes the magnesite all trend in a direction parallel to the longer direction of the outcrop and the strike of the adjoining Grenville sediments.

The banded structure generally present in the magnesite arises in part from variations in the colour of the magnesite and in part from variations in the proportion of disseminated serpentine which it contains. The width of the successive bands is exceedingly variable ranging from less than an inch to one foot, although on the whole the wider bands are most common. It was observed that the proportion of serpentine in the bands varied considerably when followed along the strike of the bands and that in places banded magnesite passed by a gradual increase in the proportion of disseminated serpentine into masses of solid serpentine.

The most conspicuous structural feature exhibited by the magnesite deposits is the prevailing presence of a lenticular form. Along the eastern margin of the main pit on the McPhee property (lot 15, range IX, Grenville township) there is a northeasterly-southwesterly trending lens of medium to coarse-grained white dolomite-magnesite 60 feet long and 10 feet wide, and 50 feet to the south of this lens there is a parallel trending lens of coarse grey dolomite-magnesite 100 feet long and 20 feet wide in which pyrite and zinc blende are disseminated. Both of these lenses apparently lie on the eastern flank of a still larger lens; for their axial planes as well as the banding in the adjoining magnesite dip towards the southeast whereas 50 feet westward the dip of the banding in the magnesite is towards the northwest. A still more striking example of the lenticular form is that exposed

in the west face of the northern pit on the same property. At the south end of this face the banding and parallel planes of parting in the magnesite have approximately an east-northeast strike and a dip gradually curving downward towards the north-northwest. At the north end of the face 80 feet farther to the north the strike is approximately east-west and the dip curves downward toward the south at the top of the face but reverses back northward at the bottom. On the face of this pit, therefore, there is apparently exhibited a cross section of the lower portion of a large distorted lens.

Deformation in Magnesite Deposits. A number of features exhibited by the magnesite deposits indicate that these masses have been intensely faulted, crumpled, and otherwise deformed: the presence of numerous slickensided surfaces, the numerous interruptions in the continuity of the banding adjoining planes of fracture, and the variations in the strike and dip in the deposits, all point to this conclusion. One of the most striking evidences of deformation in the deposits was that observed near the west side of the pit on number 3 outcrop, lot 15, range XI, in Grenville township. At this point there is a dyke of biotite-pyroxene syenite, 6 inches in width, which has been crumpled into a closely compressed anticline. The magnesite exposed in the southern pit on number 2 outcrop on the same property was observed to be granulated in places—another evidence of intense deformation. It is probable that the lenticular structure so commonly present in the magnesite deposits is also the result of deformation, since the banding in the magnesite adjoining the lenses everywhere conforms to the margin of the lens. This feature is exceptionally well shown where the magnesite adjoins a crumpled lens of serpentine which occurs in the southwestern part of number 1 outcrop on the Scottish Canadian property.

Origin. The study of the character and relationships of the Grenville magnesite seems to indicate that the deposits have been formed by the silication and replacement of Grenville limestone, and they are thus similar in origin to the mica-apatite bearing pyroxenite which occurs so abundantly in the region[1].

Phlogopite.

Deposits of phlogopite or amber mica are known to occur in the Grenville district on lot 18, range II, Harrington township; lot 20, range XI, lot 9, range VI, lots 16 and 12, range VII, Grenville township. All of these occurrences are of the usual type, consisting of diopside containing mica as scattered crystals or in irregular leads. Some prospecting for mica was done on lot 18, range I, Harrington township, by Mr. Winning and Mr. J. Wallingford during the summer of 1916, and a few barrels of mica procured.

Graphite.

The mineral graphite (plumbago or black lead) occurs widely disseminated through the rocks of the Grenville series and is especially abundant in association with the crystalline limestone member. The principal occurrences of the mineral observed in the district are situated on lot 10, range V, lot 16, ranges II and III, Grenville township; and on lot 15, range I, Harrington township. The most important deposits of graphite in the district are those on lot 10, range V, Grenville. These consist of irregular veins and aggregates of graphite associated in masses or zones with wollastonite, green pyroxene, quartz, titanite, and related minerals in crystalline limestone. The largest mass of this type on the property had an average width of approximately 5 feet, and a length of approximately 100 feet. Mining operations on these deposits have been attempted at various times during the last 70 years, but with indifferent success.

[1] Geol. Surv., Can., Mem. 98. (In press.)

Magnetite.

Magnetite occurs in the Grenville district in a number of localities in association with the Grenville sediments. The most important occurrence is found on lot 3, range V, Grenville. There the magnetite occurs in association with calcite, diopside, and other lime silicates in crumpled and broken beds interstratified with quartzite. The deposits are now largely hidden by rock debris, but, according to Sir William Logan who examined the deposit in 1857, the magnetite occurs throughout a width of 6 to 8 yards for a distance of 150 yards; the percentage of iron contained in a large part of this mass is exceedingly small, however, and the deposit as a whole is too low in iron content to have any value under present conditions of operation.

Part of Amherst Township, Labelle County, Quebec.

Since Amherst township lies only a few miles north of the Grenville district, the description of the geology of the Grenville district (pages 208-212) also applies in the main to Amherst township, and need not be repeated in detail in this section of the report. In the portion of Amherst township examined, neither the Palæozoic sediments nor the late Pre-Cambrian granite-syenite represented in the Grenville district were observed. The various other formations, on the whole, are also more uniform and occur in more continuous masses in the Amherst area; but, in other respects the geology of the two districts is the same.

KAOLIN (CHINA CLAY) AND QUARTZITE.

General Statement and Distribution.

The district in Amherst township examined by the writer in 1916 is of unique economic interest because it includes the only deposit of china clay at present mined in Canada.

The deposits of the mineral so far discovered in the district have been found in only two localities: the principal deposits in a zone approximately 1,000 feet in width extending in a north-northwest direction from lot 10 to lot 2, range VI, south in Amherst township (see Map 1676) and a small deposit occurring near Pike creek on lot 8, range IV, Amherst. The latter deposit occupies a position almost directly in line with the principal zone of deposits, and may in reality be simply another outcrop of the same zone, but the connexion cannot be definitely established, since there are no rock exposures in the intervening distance.

Character of Deposits.

In the western part of range VI south in Amherst township, there is a north-south trending drift covered ridge about one-half mile in width, which intervenes between rocky ridges of granite and syenite gneiss and from which it is separated by well marked depressions. An examination of the bedrock as exposed in a few scattered outcrops and in the bottoms of trenches, pits, and other excavations, shows that this ridge is composed almost entirely of vertical or nearly vertical beds of Grenville quartzite, trending in a north-northwest direction, and that, while on the eastern slope of the ridge the quartzite is exceedingly massive and unbroken, on the western slope throughout a zone approximately 1,000 feet in width it has been shattered almost everywhere to a friable condition.

Within this shattered zone kaolin occurs finely disseminated between the broken quartz grains, in veins following the planes of fracture and movement and in extensive masses up to 100 feet in width and several hundred feet in length. Owing to the presence of the thick overburden of glacial drift, which nearly everywhere covers the quartzite ridge, the whole extent of the shattered zone

in which the kaolin is found has not yet been determined, but, sufficient information has been obtained by means of trenches, test pits, and stripping, to indicate that the zone extends in a direction north 20 degrees east, parallel to the structural trend of the quartzite, and is continuous for at least 7,000 feet.

The most extensive deposit of kaolin so far discovered in this shattered zone is that on lots 5 and 6 where an almost continuous lead of kaolin ranging from 25 to 100 feet in width has been laid bare by stripping and test pits for a distance of 1,000 feet. Bore-holes on this deposit also show that it persists to a considerable distance beneath the surface, a depth of 150 feet in kaolin being attained at one point. While within this kaolin lead there s everywhere considerable included quartzite, either in the form of large fragments or disseminated grains, yet the determination of the kaolin contained in average samples shows that the kaolin content in the mass as a whole is not less than 35 per cent.

Throughout other portions of the shattered zone numerous kaolin leads ranging from a fraction of an inch up to 65 feet in width have been discovered at several points where the drift cover has been removed from the bedrock surface. The deposits of this character so far discovered on the various lots are the following:

Lot 2..........leads 65 and 12 feet wide in trenches.
Lot 5.......east of main deposit..........leads 5, 12, and 1 foot wide in test pits.
west of main deposit..........numerous leads from ½ inch to 4 feet in width.
Lot 6..........lead in excavation for spring.
Lot 7..........lead of kaolin one-half inch in width in broken kaolinic quartzite in cutting on Canadian Northern railway.
Lot 8..........half inch leads of kaolin in broken kaolinic quartzite in cutting on Canadian Northern railway.
Lot 10..........lead of kaolin in excavation for milk house.

At the time the kaolin deposits were examined by the writer in September 1916, a trench for a pipe-line had been excavated from the main pit to the washing plant of the Canadian China Clay Company, the bottom of which intersected the fractured kaolinic quartzite for a distance of 135 feet from the wall of the main pit southward. Continuous average samples were taken at intervals of 10 feet along the bottom of the trench and the percentage of kaolin in each sample determined by the loss of weight on removing the kaolin from the crushed material by decantation. The description of the samples and the percentages of kaolin contained in each are included in the following table:

Analyses of Kaolinic Material.

Location, feet	Description of sample	Kaolin content, per cent
1 to 10	6 leads ¼ to ½ inch wide	14½
10 " 20	4, ¼-inch leads	10
20 " 30	3, ¼-inch; 1, 2-inch; 1, 4-inch; and 1, 6-inch lead	16
30 " 40	1, 6-inch and 1, 2-inch lead	11
40 " 50	1, 6-inch lead	7¾
50 " 60	1, 2-inch and 1, 8-inch lead	15¾
60 " 70	1, 4-inch lead	11
70 " 80	2, ½-inch and one 7-inch lead	13
80 " 90	1, 2-inch lead and 3½ feet of exceedingly friable highly kaolinic quartzite	15
90 " 100	1, ½-inch and 1, 3-foot lead	17
100 " 110	No leads	2
110 " 120	Exceedingly friable but no leads	10
120 " 130	1, 2-inch lead	6
130 " 133	No leads	2¾

Average kaolin content for whole section equals 11¼ per cent.

Extent of Deposits.

Kaolin. Since the fracture zone in which the kaolin is found is covered nearly everywhere by a mantle of glacial drift from 10 to 50 feet in thickness, and since this has been only partially trenched it is possible that workable deposits of kaolin may be present in the fracture zone, which have not yet been discovered; but, of the known leads, the main deposit on lots 5 and 6, range VI, south Amherst township, is the only mass that is positively known to be of workable dimensions. It is possible that the deposit on lot 2 of the same range is also sufficiently large to be worked, but further development work is required before the actual extent of this lead can be determined.

The deposit on lots 5 and 6 is known to have an areal extent of 75 by 1,000 feet or 75,000 square feet and has been proved by borings to extend to a depth of at least 50 feet throughout this area. The volume of the ore in the deposit above a depth of 50 feet is, therefore, 3,750,000 cubic feet and since the ore contains on the average 35 per cent of kaolin, the amount of kaolin in the deposit above a depth of 50 feet is 1,312,500 cubic feet or approximately 100,000 tons.[1]

Kaolinic Wall Rock. It has been already pointed out that the zone of shattered quartzite in which the kaolin is found has a width of 1,000 feet and a length of at least 7,000 feet and that a sample taken continuously across a section of 133 feet through this shattered material contained on the average 11 per cent of kaolin. It is probable that there are considerable masses of quartzite in the shattered-zone which are more or less unbroken, and in which the kaolin content is much less than 11 per cent. If it be assumed, however, that only 10 per cent of the total fracture zone has been broken in this way there would be 3,000,000 tons of kaolinic quartzite above a depth of 50 feet.

Cornish Stone. In a small pit near the eastern margin of the fracture zone on lot 5, range VI, south, Amherst township, a rock having the following composition has been encountered.

Analysis of Cornish Stone.

Silica	72·96
Alumina	17·30
Potash	6·41
Lime	1·50
Magnesia	0·65
Iron	0·10
Water	1·10

This rock has, therefore, the composition of Cornish stone. The quantity of this material present is unknown, however.

Use of Materials Contained in Deposit.

The kaolin obtained from the deposit, as the following analysis indicates,

Analysis of Kaolin.

Silica	46·13
Alumina	39·45
Iron oxide	0·72
Lime	None.
Magnesia	None.
Potash	0·20
Soda	0·09
Loss on ignition	13·81
Total	100·40

Analyst, G. E. F. Lundell.

[1] Assuming 13 cubic feet of kaolin as equivalent to 1 ton.

is exceptionally pure and consequently is eminently suitable for the manufacture of chinaware, porcelain, pottery, and similar materials. At present the china clay is being sold to the paper manufactures to be used as paper filler.

Tests of the physical character of the china clay made by Mr. J. Keele, of the Mines Branch, are described by Mr. Keele as follows: "The washed kaolin requires 45 per cent of water for tempering. It has a fair amount of plasticity, but like all kaolin, it works rather short and crumbly. The shrinkage on drying is 7 per cent.

Cone	Fire shrinkage %	Absorption %
010	3·0	34·3
06	3·6	34·3
1	4·5	32·0
5	9·3	20·0
9	11·3	17·0
34	Softens	

"This material has greater plasticity and higher shrinkages than most of the standard brands of washed kaolin or china clay. The samples for testing were taken from near the surface, but at deeper levels, it is possible that the kaolin will not be so plastic and not shrink so much on drying or burning."[1]

Experiments have also been made by Mr. Keele which show that the china clay can be mixed with ordinary marine clay for the manufacture of refractory brick. Notes on this experiment, supplied the writer by Mr. Keele, are as follows:

"Owing to the fact that fireclays are of rare occurrence in central Canada, it seemed desirable to experiment with the crude kaolin from St. Remi, in order to find out if refractory brick could be made by using this material.

"The crude kaolin is highly refractory and when moulded into brick shapes and burned at the ordinary temperatures of burning firebrick the resulting brick are rather soft and porous, with checked or cracked surfaces. A product like this would not stand transportation well, besides it would be structurally weak. It, therefore, seemed necessary to introduce some fluxes as a mixture in the kaolin in order to produce density and strength of body. The material selected was the marine clay occurring in the valley of Rouge river, which contains a high percentage of fluxing impurities and consequently is rather easily fusible.

"The mixtures used in the test consisted of 10 to 20 per cent of marine clay and 90 to 80 per cent of crude kaolin. Bricks made from this mixture were burned in the firebrick kilns at St. Johns, Quebec, at a temperature of 2,400 degrees F. The resulting brick had all the appearance of ordinary commercial firebrick, being dense and strong.

" A small portion of one of the brick was placed in an electric kiln and raised to a temperature of 3,000 degrees F. without being sintered.

The results show that a kaolin firebrick can be made, probably equal to many of the standard imported brands, which would give good service for such uses as stove linings, boiler settings, brick kiln linings, lime kiln linings, etc. It is not known how the material would behave in contact with slags in metal furnaces, but this test will be made later on. The discoloured kaolin can also be mixed with the white kaolin to produce firebrick."

[1] Keele, J., "Preliminary report on the clay and shale deposits of the province of Quebec," Geol. Surv., Can., Mem. 64, pp. 4–5.

In addition to the uses to which the kaolin itself can be applied, the kaolinic wall rock can also be used for the manufacture of silica brick and as foundry sand. Experiments made with this material to determine its suitability for the manufacture of silica brick are described by Mr. Keele in the following statement.

"The material was crushed to pass a 10-mesh screen and milled with a little water until it became somewhat cohesive. At this stage it could be moulded into brick shapes by hand, and re-pressed by machinery when partly dry. The bricklets were burned in a gas kiln to 1,300 degrees C., and afterwards in an electric resistance furnace to 1,530 degrees C.; a small portion of one of the bricklets being finally raised to 1,650 degrees C. The bricklets burned to 1,530 degrees were hard and dense, and showed that a fused bond between the kaolin and quartz grains was effected. Raising the temperature to 1,650 degrees changed the character of the material only slightly, there being no indication of failure through softening, and it would probably stand a temperature of 1,700 degrees just as effectively. These results seem promising for such uses as puddling, malleable, cupola, and crucible furnaces, or for converter linings and glass making furnaces."

The experimental tests to determine the qualities of the crushed wall rock as a foundry sand are being performed by Mr. H. Cole of the Mines Branch, but are not yet complete.

GRAPHITE.

Graphite is reported to occur in several localities in Amherst township, the most important deposit being found on lot 16, range VI, north. On this lot the graphite occurs in crystalline limestone as irregular veins and aggregates associated with wollastonite, pyroxene, calcite, titanite, and numerous other minerals of the lime silicate class. Throughout a considerable part of the masses in which the graphite is found the proportion of graphite is large but the masses are so irregular in form and discontinuous that the proportion of graphite to the total amount of rock actually mined in procuring the ore is exceedingly small.

NORTHERN PORTIONS OF PONTIAC AND OTTAWA COUNTIES, QUEBEC.

(*J. Keele.*)

INTRODUCTION.

A few weeks of the field season of 1916 were spent in the northern part of Pontiac and Ottawa counties, Quebec, drained by tributaries of Gatineau river (Figure 8). A search for kaolins or residual clays was the primary object of the journey, but as the region was almost unknown from a geological point of view, this brief account of the reconnaissance has been written. The route followed led from Maniwaki northward, principally along the valley of the Désert river to the Gens-de-terre river, and thence by portaging to Bark lake. A network of lakes and their connecting streams was traversed by canoes and the return was made by Gens-de-terre and Gatineau rivers.

Acknowledgments for courtesies and valuable assistance are due to Mr. W. C. Hughson, of the Gilmour and Hughson Company, and to Mr. J. Quaile, their agent at River Désert.

TOPOGRAPHY.

The area drained by Gatineau and Désert rivers lies wholly within that great physiographic province, the Laurentian plateau, which consists of rocky, wooded hills and ridges, with intervening valleys containing swamps, lakes, and streams.

The highest ridges form a fairly even skyline at 1,200 to 1,300 feet above sea-level. Only an occasional dome or monadnock rises above this elevation.

The greater part of the region appears to be underlain by granite gneisses of fairly homogeneous character, with no definite dip or strike. Erosion in these

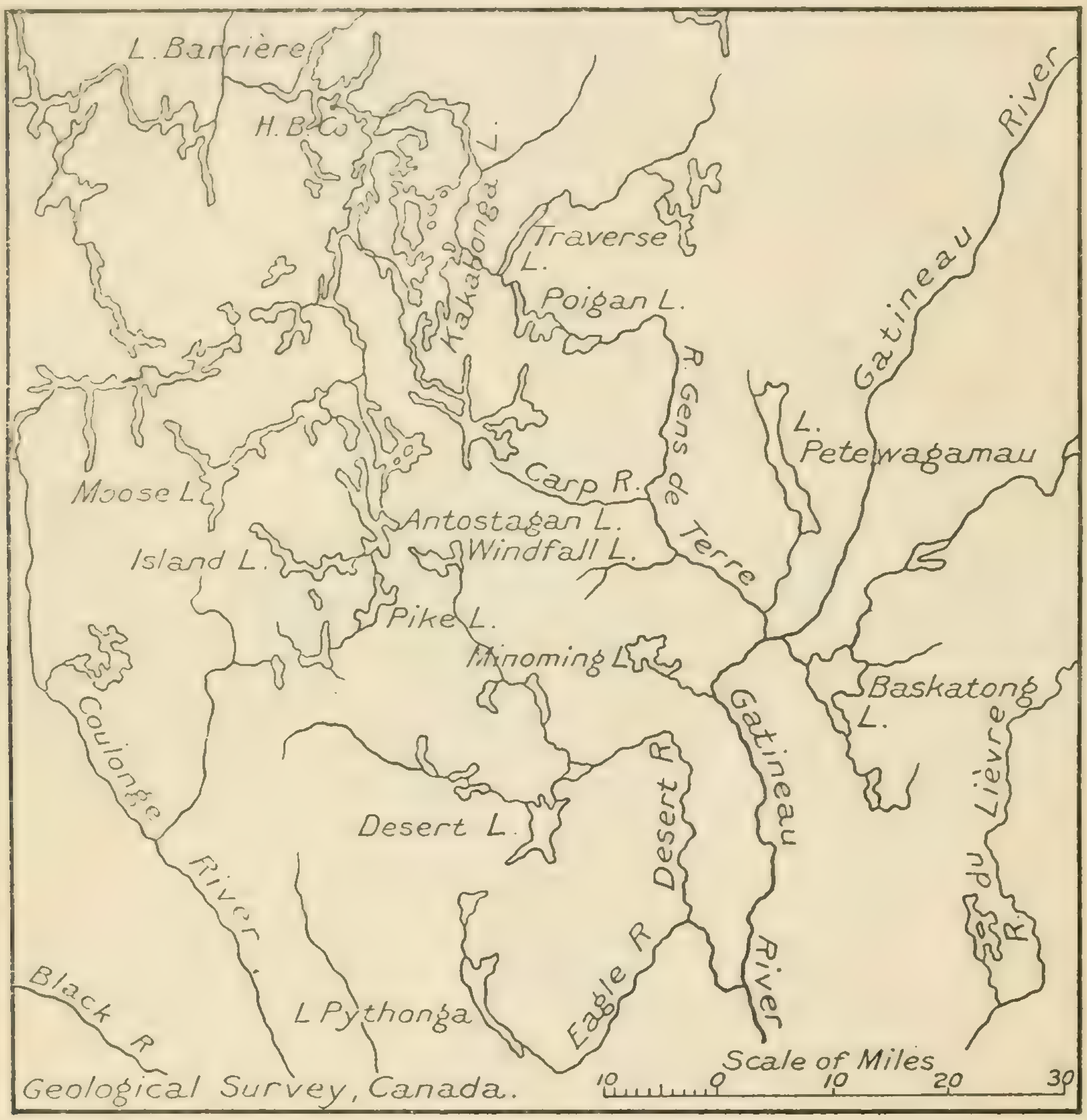


Figure 8. Northern part of Pontiac and Ottawa counties, Quebec.

rocks proceeds irregularly by quarrying along joint planes. Where the underlying rocks are the schists and limestones of the Grenville series, the valleys have a more definite trend or alignment.

Gatineau river follows the rocks of the Grenville series in its southern course, except where protruding ridges of granite gneiss divert it from its general course. The broad portions of the valleys appear to be underlain by comparatively soft rocks, such as crystalline limestone; but they are now for the most part floored with deposits of sands and gravels of fluvioglacial origin.

During late Pleistocene time marine waters extended up Gatineau and Désert valleys for some distance above Maniwaki, reaching approximately 700 feet above present sea-level. A considerable amount of clay and silt was deposited

in the lower part of the valleys during this submergence. Subsequent slow uprising of the land enabled the river to carry off much of these sediments, but a large portion still remains in terraces bordering the river.

The scenery of the Gatineau valley is very striking, especially on some of the reaches of the river above Maniwaki. The great scenic feature is the succession of falls and rapids in the part of Gens-de-terre river known as the Maligne, where the river flows through a narrow canyon between two high granitic ridges. The maze of lakes and channels at the head of the Gens-de-terre river is situated high up on the plateau, and, consequently, the bordering forest-clad ridges are not high, in few places rising over 200 feet above the lake-levels.

DRAINAGE.

An extensive group of lakes, of which Kakabonga is the largest, occupies the highest elevation among the western tributaries of Gatineau river, their principal discharge being eastward by Gens-de-terre river. The area of the basin outside that occupied by the lakes is not large, as rivers flowing north, west, and south head in the immediate vicinity. During high-water stages these lakes spill over into the headwaters of the Ottawa river by an outlet on Barrière lake. A dam built by the lumbermen prevents an overflow at low water. Water from Antostagan lake, on the same drainage system, is diverted by an artificial cutting southward to Désert river, its previous outlet to Wolf lake being closed by a dam.

The depth of water in the lakes is not very great. The depth in Big and Little Wolf lakes varies from 20 to 56 feet, an average of six soundings being 33 feet. The average depth in Rapid lake is 25 feet. The deepest water was found in Kakabonga lake, soundings in its widest part giving a depth of 250 feet. Lake Traverse on the upper part of Gens-de-terre river is unusually deep for such a small body of water, the sounding giving depths of from 104 to 125 feet. The deepest sounding in Big Poigan lake on the same river was 90 feet and in Little Poigan 125 feet.

All the lakes appear to be held in by glacial drift at some point, none of them being entirely rock rimmed. Many of them spill their water into the next lower lake over a rock barrier, the older outlet being concealed beneath drift.

The water of Antostagan, Pike, and Island lakes is undoubtedly held from flowing southward through Windfall lake to the Désert river, by a barrier of boulder drift.

The upper part of Gens-de-terre river does not flow in a definite valley; it simply spills from one depression to another. Below Little Poigan lake it flows through an old glacial lake bottom as far as the head of the portion of the river known as the Maligne. At that point it enters a narrow channel between two granite ridges, through which it descends by a succession of cascades for a distance of 9 miles with a drop of about 120 feet. Beyond this the bed of the lower part of the river is entrenched in the silts and sands of an old glacial lake, here and there falling over a rocky ridge which it has uncovered. The Gatineau river consists of a chain of comparatively still-water stretches, connected by falls or rapids over bedrock barriers. It does not appear to occupy a definite valley above Brulé rapid, but below that point it enters an old, well-defined valley lined with terraces of alluvium. This part of the valley has not, generally, the gorge-like aspect of the lower portion, near the Ottawa valley.

The elevation of lake Kakabonga is between 1,100 and 1,200 feet above sea-level, probably about 1,150 feet. The total descent to the junction of Gatineau and Ottawa rivers is, therefore, about 1,000 feet. The step-like character of the drainage over rock barriers is contrary to what might be expected on such an

ancient land surface where a thoroughly graded stream would be looked for. This cannot in all cases be accounted for by stream diversion, since the river flows over rock barriers in portions of its course where it evidently occupies its old pre-Glacial channel.

AGRICULTURE AND FORESTS.

The greater part of the region drained by Gatineau river and its tributaries consists of rocky ridges and knolls, and the area available for agricultural purposes is mostly confined to the valley bottoms.

One of the pleasantest features of the Gatineau river in the spring and summer months is the strip of verdure along the bank of the river, which ends abruptly at the background of forest covered or rocky hills. This strip varies from about half a mile to a mile in width, and reaches up to lot 20 in the township of Lytton, a distance of 17 miles above Maniwaki, in both the Désert and Gatineau valleys. It comprises the best land available for agriculture in the region, and owes its fertility to the silt deposit. Even when the silt subsoil is underneath a foot or two of sand, good crops can be grown, as the water retained in such abundance by the silt supplies moisture to the sand; but where the sand covering is too thick the benefit of the underlying silt is lost. Unfortunately this is the case over most of the wide depression in the lower part of Gens-de-terre River valley, where the only farm, that of the Edwards Company, is kept productive by constant application of stable manure.

An isolated patch of farm land is situated between Gatineau river and Baskatong lake, where the silts of an old glacial lake underlie a sand covering in some places not too thick for the successful cultivation of buckwheat, turnips, oats, potatoes, and other crops.

The fluvioglacial gravels and sands which rest on the porous boulder drift are unsuitable for cultivation. Such areas are seen in the valley of Castor Blanc creek and between the northern boundary of Sicotte and Lytton townships and Gens-de-terre river, where the land is mostly a barren waste, now that its crop of commercial timber is cut or burned off. The sand areas in the region around Kakabonga and its tributary group of lakes likewise offer very little possibility for agriculture. The sands, owing to the exhaustion of the small amount of humus derived from the old forest cover, become barren in about four years unless plentifully manured. A good vegetable garden is maintained at the Gilmour and Hughson depot on Bark lake by constant manuring, helped without doubt by the tempering influence on the climate of the large bodies of water, for at some distance away from the lakes frost occurs every month of the year.

It is interesting to note that a large bee-keeping establishment is successfully conducted by Mr. S. Martineau a few miles north of the village of Montcerf. The bees derive the honey principally from the wild raspberry, fireweed, goldenrod, and other plants of the burnt lands.

The valleys of Désert and Gatineau rivers were famous for pine in the early days of the lumber industry. The pine in the southern portions of Pontiac and Ottawa counties has been exhausted by cutting and by fires, and is only found at present in merchantable quantity and size on the northern tributaries. The land surrounding the lake basins drained by Gens-de-terre river is now one of the principal areas containing pine. The area is controlled by two large lumber companies and is so large that cutting can be carried on perpetually if forest fires are kept down.

GENERAL GEOLOGY.

The bedrock of the region, which is all Pre-Cambrian, includes two main groups: (1) granite gneisses of intrusive origin, generally referred to as the Lauren-

tian or Ottawa gneisses; (2) highly metamorphosed and contorted rocks, generally known as the Grenville series. Rocks of both groups are intersected by pegmatite, and some minor irregular masses of greenish pyroxenite rocks were seen as intrusions into the Grenville series.

GRANITE GNEISS.

Some of the knolls and ridges of granitic rocks, surrounded by the Grenville series, may not be of the same age as the prevailing Laurentian gneisses; but more detailed work would be necessary to determine this point. The late Pre-Cambrian igneous intrusives, such as diabase and lamprophyre in dykes and irregular masses, which intersect all the older rocks in the Ottawa valley, were not observed in the region traversed.

In the southern part of the area the granite gneisses occur in isolated masses, generally conspicuous by their elevation and ruggedness, the valleys and lower elevations between being underlain by the rocks of the Grenville series. Alternating granite gneisses and Grenville rocks continue up Désert River valley for about 35 miles north of Maniwaki. Beyond this point the granite gneiss ridges predominate, finally merging into one continuous mass of considerable extent. Bark, Rapid, Wolf, Antostagan, and the greater part of Kakabonga lake lie within this great area of granitic rocks. The geology of the region to the west of these lakes is unknown, but it is probable that the granitic rocks extend continuously to the known areas of these rocks on the Ottawa river. The gneisses show little variation in colour, texture, and composition, and not much difference in structure. Grey hornblende granite gneiss is the prevailing type, and it with pink biotite gneiss constitutes hundreds of square miles of the country rock. These rocks are fine-grained as a rule, and pegmatite phases although not uncommon do not appear to be abundant, except near the contacts with the Grenville. Various phases of the gneisses are found, from a massive variety with little or no foliation to one in which intense foliation simulates thin bedding. The main masses of granite gneisses appear to contain little or no absorbed or included material of the Grenville series, although near the contacts with these rocks their influence is seen.

GRENVILLE SERIES.

Rocks of the Grenville series occupy a relatively large area in the southern portion of the region and outcrop in many places in the Désert and Gatineau valleys. To the north they are completely cut off for some distance by the granite gneisses, but they reappear in smaller isolated patches on the upper part of Gens-de-terre river as far as the east shore of Kakabonga lake, and on Barrière lake.

The rocks of the Grenville series are supposed to have originated as sediments, mainly shales, limestone, and sandstone, and to have once spread over a large area of southern Quebec and Ontario. The vestiges which now remain in the sea of intrusive igneous rocks are so altered to sillimanite-garnet gneiss, crystalline limestone, and quartzite that their sedimentary origin is scarcely recognizable. The crystalline limestone is the most conspicuous and easily recognized member. It occurs in considerable abundance in the lower part of the Gatineau valley and has a marked influence on the topography. The wide depression at Kazabazua, 35 miles below Maniwaki, one of the most notable features of the valley, is carved almost entirely out of this comparatively soft rock. In the Désert valley and apparently also in the Gatineau valley the relative proportion of the crystalline limestone to the other rocks decreases to the north.

The most important northerly area of Grenville rocks is a belt with a width of about 16 miles across the strike, lying between Little Poigan lake on Gens-de-terre river and the east shore of Kakabonga lake. Its north and south extension is unknown, except that it is cut off completely to the south by the granite gneisses and it occurs northward on Washkiga lake. Another area, which is probably smaller in extent, occurs on Barrière lake. The crystalline limestone, although extending as far north as the lake, is in very small amount, the principal rocks being quartzites, mostly thin-bedded, and garnet gneisses.

Barrière lake is the most northerly point to which rocks of the Grenville series have been continuously traced from the south.

PLEISTOCENE.

Glaciation.

Ice appears to have accumulated over the region in Pleistocene time to a thickness at least sufficient to submerge the highest ridges. The only evidences now left of its visitation are occasional low heaps of stony drift in the form of marginal moraines and drumlins, and the smooth, rounded outlines of the bare rocky hummocks in the valley bottoms. Although occasional grooving exists on the rock surfaces, scarcely any traces of striation marks remain, especially on the granite gneisses. The main features of the topography are pre-Glacial, and only a comparatively small amount of erosion can be attributed to ice action. There is no indication of more than one general Pleistocene glaciation, and the drift deposits show no evidence of readvance or oscillations in the extent of the ice-sheet after it first commenced to withdraw from the region.

Glacial Deposits.

The unconsolidated or superficial deposits connected with glacial phenomena in the region are of four kinds: boulder drift, gravels, sand, and silt. Most of these materials were formed and accumulated during retreating and melting stages of the ice. They are simple in their arrangement, and show none of the complexity which characterizes many of the glacial drift deposits in the St. Lawrence and Great Lakes basins.

Boulder drift is the residue left after the melting of the ice-sheet and is made up of material picked up and incorporated in the ice during its passage. The name boulder drift is used here instead of boulder clay as no true boulder clay was seen north of Maniwaki. The drift is spread in a thin sheet over the sides and bottoms of the valleys and on the tops of some of the rocky hills and ridges, although many of these are bare. Occasionally the boulder drift is heaped up in low moraines or drumlin-like forms. It consists of large and small partly rounded boulders and fragments of bedrock, with gravel, sand, and a small amount of silt, all mixed together without indication of sorting or sizing. It generally rests on bedrock without any intervening stratified materials and forms the base of the other kinds of glacial deposits. An analysis of the boulder drift at several points in the lake region showed that 98 per cent of the deposit was composed of the wastage of the underlying bedrocks, and only in the main valley of Gatineau river did it show an admixture, to any extent, of far transported material. A careful scrutiny of the boulder drift over large areas failed to reveal pre-Glacial residual, or transported clays incorporated in it. This fact seems to indicate that accumulations of clays, due to rock weathering in situ, were of rare occurrence over this area for some time before glaciation occurred; for even small amounts of residual clays influence the colour and texture of glacial drift so much that their presence is unmistakable.

Gravels. The gravel deposits occur in sheets and in heaps called eskers and kames. In the latter they have a considerable admixture of sands, or may contain streaks and lenses of sand. These gravel heaps were probably formed by powerful streams issuing from ice margins which had grade enough to carry or roll large stones as well as small ones. They appear to mark halting stages in the northward retreat of the ice front.

The stones in the gravel deposits are all fairly well rounded, and mostly between 3 and 9 inches in diameter. The gravels occur irregularly at various points and at various levels, but they generally merge into sandy plains. One of the largest gravel deposits seen extends from the Désert River valley to the banks of the Gens-de-terre, a distance of about 15 miles. The wagon road crossing it passes between a succession of gravel heaps and kettle lakes, in places following esker ridges and in places traversing intervening stretches of sand. Similar gravel deposits form a ridge about a mile wide crossed by Gens-de-terre river about 5 miles below the Lepine farm, and another ridge is cut by Gatineau river at Lion chute about 10 miles below the mouth of the Gens-de-terre. Gravels were noted also at a few other localities lower down the Gatineau valley.

Sands. Sand deposits cover extensive areas in the lake region as well as in the main river valleys. Some of the sand deposits are intimately connected with the gravel mounds of the ice front and are arranged in broad flattened ridges or fans. At other places the sands form plains which appear to have been old lake bottoms. Very extensive sand mounds, fans, or deltas are seen on both sides of Rapid lake, as far north as Barrière lake and also at the head of Kakabonga lake, while deposits of lesser extent occur on Wolf lake and Bark lake. The principal sand-plain occurs on the lower part of Gens-de-terre river and reaches northward to Baskatong lake and southward to Lion chute on Gatineau river. The lower part of the valley of Castor Blanc river in the township of Aumond is deeply filled with sand, and most of the smaller valleys and depressions opening on the Gatineau are floored with sand.

Gatineau river shifts immense quantities of sand down-stream every year. All the basins below rapids contain extensive bars visible at low water. The shape, size, and position of these bars are constantly changing.

The fluvioglacial sands, especially in the lake region, are rather fine-grained, as shown by the analyses of two samples, one collected at Barrière lake and one at Rapid lake. These sands all passed through a 20-mesh screen, and a little over 90 per cent passed through a 150-mesh screen. The material retained on screens coarser than 150-mesh was composed mostly of flake mica with a less amount of hornblende grains. The material that passed through the 150-mesh was mostly all clean, angular, white quartz grains. The sample from Barrière lake contained 8·23 per cent of silt and that from Rapid lake had 35 per cent.[1]

At several points on the lake shores, particularly in the vicinity of the rocks of the Grenville series, the recent local sands are made up of a large amount of garnet and quartz as well as grains of zircon, tourmaline, and ilmenite, the reddish colour of the sands being due to the large amount of garnet present. The recent sands along Gatineau river are reddish in colour from feldspar grains, and rather coarse-grained compared with the fluvioglacial sands.

Silt. Silt is the finer-grained product of glacial erosion and is capable of suspension and transportation in water with very little current for a considerable distance before settling to the bottom. It is like clay in appearance but lacks plasticity. It occurs in considerable thickness up the valleys of Désert and Gatineau rivers to a distance of nearly 20 miles above Maniwaki. Farther north it occurs in patches on Gatineau and Gens-de-terre rivers as far as the Lepine farm. No silt deposits are visible in the lake region at the head of the Gens-de-terre

[1] Analysis by L. H. Cole, Mines Branch.

but they doubtless exist in some of the lake bottoms. The silts are laid down in thin layers, about four to an inch, with a parting film of fine sand between each layer, and in some places sand beds are included in the silt deposit. The colour is lead grey when moist and light grey when dry, and they are fine enough to pass through a 200-mesh screen. Many of the sections on the river banks show thicknesses of 30 feet for the silt deposit, and a thickness of 75 feet was observed on Gatineau river below Big Eddy chute. The silts are very uniform in character throughout the region; two samples collected at points over 100 miles apart gave identical results on testing.

Glacial Lakes and Estuaries.

There is evidence that in post-Glacial time a series of glacial lakes existed which have now disappeared through the down-cutting of their outlets and existing lakes seem to have once had a larger extent. The water-level in the basin holding Kakabonga, Bark, Rapid, and Barrière lakes was 30 feet higher in elevation than at present, as is shown by the terraces and beach ridges on the fluvioglacial sand deposits.

There are several instances of former ponding of water behind barriers of glacial material, both on Gens-de-terre and Gatineau rivers. One of the best examples was seen on the latter river in the vicinity of Baskatong creek. This lake appears to have been about 15 miles long, and to have included the present Baskatong lake as well as 10 miles of the lower portion of Gens-de-terre river. The stratified silts which were laid down on this lake bottom are visible at many places on the river banks. The glacial dam which held in the lake is situated at Lion chute, and consists of about 50 feet of boulders and outwash gravels, overlying granite gneiss. The elevation of the lake was about 800 feet above present sea-level.

The silt is absent from the banks along the river for a distance of from 8 to 10 miles below Lion chute but appears again below Brulé rapid, at lot 19 in the townships of Sicotte and Lytton, and continues southward until it merges into the estuarine clay below Maniwaki. A cut bank 75 feet high in the basin below Big Eddy chute, a little over 2 miles below Brulé rapid, is composed entirely of stratified silt built up in layers of about a quarter of an inch in thickness with films of sand between. On the supposition that these layers represent yearly increment, the time occupied in building this deposit was 3,360 years. The cultivated terraces bordering the river between Brulé rapid and Maniwaki are the remnants of this silt deposit which once filled the valley.

Marine waters extended up the Ottawa and Gatineau valleys in late Pleistocene time to a point some distance above Maniwaki, the height above sea-level to which it reached being approximately 700 feet. The highly plastic, stiff, massive clay which is the characteristic type of marine sediment in the lower part of the Gatineau valley is entirely absent at and above the junction of Gatineau and Désert rivers.

As there are no precise levels available in the upper part of the Gatineau valley, it is impossible to fix the upper boundary of estuarine deposits. The silts below Brulé rapids are almost exactly similar to those of the glacial lake above Lion chute, and no fossils of any kind have so far been found in them; yet it is probable that they are part of the marine sediments, for the 700-foot level appears to be situated at or near Brulé rapid.

The sediments in the lower part of the Gatineau valley indicate by their succession that they were laid down in a rising water body. The lower portions are stratified sands and silts representing shallow water accumulations, while the upper portions are highly plastic, massive clay, representing deep-water

deposits. The stratified silts above Maniwaki, where the water was continuously shallow, probably correspond to the silts lying below the marine clay in the southern part of the valley.

ECONOMIC GEOLOGY.

The most productive mineral areas are those underlain by the Grenville series and accompanying intrusives and those lying along the contacts between the Grenville and Laurentian gneisses. The non-metallic minerals are of special importance and include materials much sought after for industrial uses now that foreign supplies are not available. This is especially true of magnesite, kaolin, and corundum, and to a less extent of graphite, phosphate, mica, feldspar, talc, and fluorspar.

Several producing mines are in operation in the southern portion of the region within 30 miles of the Ottawa river, in Argenteuil, Labelle, Ottawa, and Pontiac counties. The present investigation has shown that there are large areas of Grenville rocks in the northern parts of these counties which may well repay the labour of prospecting, both for the above minerals and for rarer minerals which are found elsewhere in these rocks.

The ores of molybdenum, lead, and zinc are the principal metallic products of the region. A deposit of molybdenite of economic importance occurs in Egan township a few miles north of the village of Montcerf[1] and recently a promising occurrence was found within 2 miles of Maniwaki.

Graphite occurs in small scales disseminated throughout many of the masses of crystalline limestone. It was seen in larger amounts interlaminated in the thin beds of the Grenville quartzites on Kakabonga and Poigan lakes, and may be found in commercial quantities within some of the Grenville areas in this region.

Garnet occurs abundantly in grains disseminated through the schists of the Grenville series, and gives a reddish colour to the sands derived from them. Massive garnet appears to be rare in Quebec, though it has never been specially looked for. It is crushed and used as an abrasive, particularly for making sand belts used in the woodworking industry.

Although no traces of kaolin or china clay were seen in the course of the journey, further examination and inquiry regarding it are desirable. The large commercial deposit in the Grenville quartzite in Amherst township, Argenteuil county, was found beneath boulder drift, by a farmer, while sinking a well. Surface indications are of little avail in the search for deposits of this kind except to one accustomed to prospecting for clays. To such a one even very small quantities of white, yellow, pink, or grey residual clays are very noticeable among the monotonous drab or grey of glacial drifts, and furnish a clue to the position of the concealed deposits.

Extensive graphic granite masses and feldspar dykes in the vicinity of Maniwaki are also worth examination.

The sands of the region are too high in iron to be used as glass sands or for refractory purposes, but some of the quartzites of the Grenville series are pure enough for the manufacture of silica refractories.

The Désert and Gatineau silt furnishes the only material so far seen that is suitable for brick-making. It is easy to work, mould, and dry in the raw state and might be suitable for making common brick by the soft-mud process. It burns to a very porous light red body at low temperatures, with very little fire shrinkage. Owing to low plasticity it is not suitable for the manufacture of tile or other products that have to pass through a die.

[1] **Walker, T. L.**, "Molybdenum ores of Canada", Mines Branch, Dept. of Mines, p. 30.

HEADWATERS OF NOTTAWAY, ASHUAPMUCHUAN, ST. MAURICE, AND GATINEAU RIVERS, NORTHWESTERN QUEBEC.

(*H. C. Cooke.*)

The field season of 1916 was spent on a geological reconnaissance of the area lying between the National Transcontinental railway on the south, and the district explored during the field seasons of 1912, 1914, and 1915 on the north. This territory on the west adjoins that studied by M. E. Wilson, W. J. Wilson, and J. A. Bancroft, and extends eastwards as far as St. Maurice river. A fairly complete examination was effected by following the very numerous watercourses which intersect it. These are tributary to Nottaway river in the northern and western parts of the area, and to St. Maurice in the southeastern portions; the northeastern corner of the district is drained by Ashuapmuchuan river to lake St. John, and a narrow strip on the south by Gatineau river. In addition to the exploration of this region a section down Gatineau river from Parent village, on the Transcontinental railway, to the city of Ottawa was examined.

The greater portion of this large area is underlain by granite gneiss which contains large and small fragments of the Grenville series of sediments in various stages of digestion. On the north bodies of older rocks are also found. These include several areas of ancient lavas on the Opawika river, probably to be correlated with the Keewatin of the districts to the southwest, and an area of the Grenville series around the headwaters of Opawika and Nikabau rivers. The results of the examination of these areas are not given here, as they will be embodied in a Museum Bulletin, shortly to be published. It may be briefly stated, however, that some very interesting determinations of the structure of both these series of rocks were made, and that a very definite succession was found to obtain in the lava series; while the Grenville series was found to rest with perfect structural conformity on the surface of the lavas.

The district is extremely barren and will probably be of little value for any purpose but that of a fish and game preserve. From a mineral standpoint, the granite gneiss which underlies most of the area has everywhere been found to be barren. The lavas on the north are slightly mineralized in places and might repay prospecting; but without railway communication any deposit found in them will be valueless on account of the difficulty of access. The soil of the region is mainly sand and gravel deposited in the beds of former shallow, glacial lakes; so that the agricultural outlook is not bright, except on the Lake St. John slope where some areas of clay are found. The timber resources are probably the most valuable, at least on the south side of the Height of Land, and are being exploited by several companies; but even these have been greatly depleted by large forest fires, which, in the absence of adequate fire protection, have swept large areas. It is probably not too much to state that one-third to one-half of the timber north of the National Transcontinental railway has been destroyed by fire in the last fifteen years.

THETFORD-BLACK LAKE MINING DISTRICT, QUEBEC.

(*Robert Harvie.*)

In 1915 a detailed investigation of the geology of the Thetford-Black Lake area was begun by the writer assisted by Mr. J. K. Knox. During the past season, owing to the writer having transferred his services to the War Purchasing Commission, Mr. Knox carried on the field work with such supervision and aid

Canada
Department of Mines

Hon E L Patenaude, Minister R G McConnell, Deputy Minister

GEOLOGICAL SURVEY

Issued 1917

Structural Section along line A B
Horizontal and Vertical Scale 63360

LEGEND

RECENT AND PLEISTOCENE
- Q Alluvium and glacial deposits

POST ORDOVICIAN
- 8 Dikes
- 7 Metamorphic hornblende schist
- 6 Brecciated amygdaloidal ellipsoidal contact phase of the serpentine series
- 5 Granite
- 4 Gabbro diorite
- 3 Pyroxenite
- 2 Serpentinised pyroxenite
- 1 Serpentinised dunite and peridotite

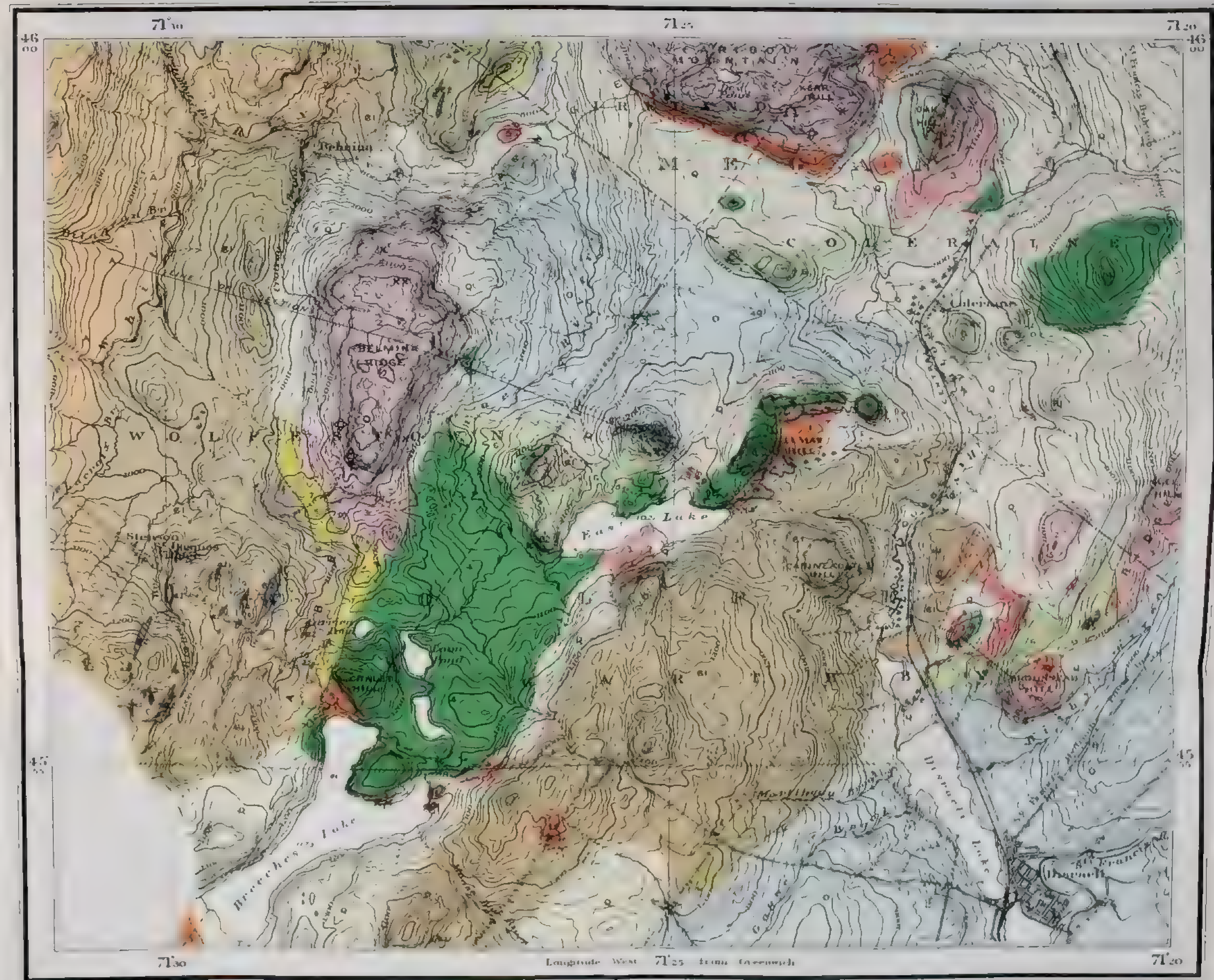
ORDOVICIAN ?
- O Farnham black pebbly slate chert

CAMBRIAN ?
- Є2 Sillery ? red and purple slates sandstone lenses
- Є1 L'Islet quartzite

PRE CAMBRIAN
- A Bennett quartzite schist

Symbols

- Chromite
- Asbestos
- Prospects
- Geological boundary *defined*
- Geological boundary *approximate*
- Geological boundary *assumed*
- Dip and strike



C O Senecal Geographer and Chief Draughtsman
A Jones Draughtsman

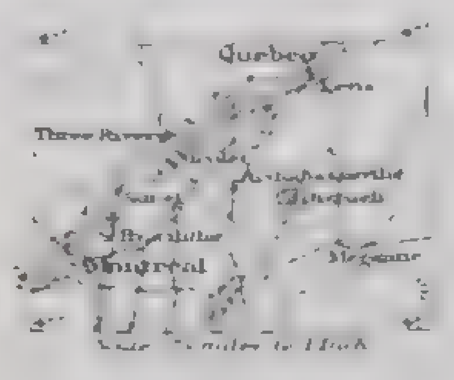
Catalogue No 1617

LEGEND

- Streets and buildings
- Schools
- Roads *to or town ship boundaries*
- Post offices
- Roads *good*
- County boundaries
- Roads *poor*
- Township boundaries
- Bush roads paths
- Rivers and lakes
- Railways
- Watercourse *with intermittent flow*
- Mine tramways
- Marshes
- Power lines
- Contours *showing form of terrane and elevations above sea level; interval 20 feet*
- Bridges
- Figures *showing heights in feet above sea level*
- Churches

Geographical position based on the latitude and longitude of triangulation station "Thetford Mountain" established by the Geodetic Survey of Canada

Approximate magnetic declination 17°30' West



COLERAINE
MEGANTIC AND WOLFE COUNTIES
QUEBEC

Scale 1/63360

Miles

Kilometres

1 MILE TO 1 INCH

GEOLOGY

R HARVIE, (IN CHARGE) 1915 1916
J R KNOX 1915 1916

TOPOGRAPHY

D A NICHOLS 1913 1914
B C McLEAN, (TRIANGULATION) 1913

To accompany Memoir by R Harvie

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as could be given during two brief visits. The accompanying summary report by Mr. Knox is an indication of the satisfactory manner in which he carried on the investigation.

Approximately two-thirds of the area has now been examined in detail, including the portion which the preliminary work showed would furnish the key to the interpretation of the whole sheet, namely the part dealt with last season by Mr. Knox. It has accordingly been thought advisable to make Mr. Knox's results available at once and the major features are accordingly dealt with in his summary report.

Southwestern Part of Thetford-Black Lake Mining District (Coleraine Sheet).

(*J. K. Knox.*)

INTRODUCTION.

GENERAL STATEMENT AND ACKNOWLEDGMENTS.

The writer spent the field season of 1916 in a continuation of the study of the Thetford-Black Lake map-area. Work in this region commenced in 1915 but, as attention was directed chiefly to the sedimentary series, little new light was thrown on the problems of the igneous rocks. During the past field season, on the other hand, the igneous complex was made the subject of particular study.

Work began on June 26 and closed September 30. Throughout the summer headquarters were at Coleraine. Mr. A. B. Gilbert, as assistant, rendered very ready, efficient, and intelligent service. The writer wishes to acknowledge his indebtedness to Mr. Robert Harvie, under whose direction the work was carried on, for much helpful criticism and suggestion.

The Thetford-Black Lake map embraces an area of about 225 square miles. It was prepared by D. A. Nichols of the topographic division and will be published on a scale of 4,000 feet to 1 inch, with contour intervals of 20 feet. At the close of the past season, two-thirds of the area had been mapped in a preliminary fashion with regard especially to the sediments, and the southwest quadrant virtually completed. It is with this latter portion, including an area of about 65 square miles and to which the name Coleraine sheet is being given, that this report will deal.

In preparing the accompanying map, outcrops were located, wherever possible, by the use of the topographic base. All important contacts were run by plane-table survey, using fore and back sights, or, where this was impossible, by compass and tape.

LOCATION AND MEANS OF TRANSPORTATION.

The Thetford-Black Lake district lies in the Eastern Townships of the province of Quebec, about 75 miles almost due south of Quebec city on the St. Lawrence river, and 75 miles north of the International Boundary.

The Quebec Central railway, which runs from Sherbrooke to Quebec city, passes through the area from north to south and affords excellent transportation facilities.

One of the two important highways running through eastern Quebec from the United States to the St. Lawrence, parallels the railway line, more or less

closely, for more than 100 miles. Farther south, the road is of fairly good macadam or gravel, but for the 12 miles across the map sheet from Disraeli to Black Lake, it is of clay, sand, or at best thinly gravelled, and usually in very bad condition. This highway possesses many scenic attractions and could be made very popular with tourists from the neighbouring states if it were put in good shape for automobile traffic. Bad as the road is, the traffic is considerable and increasing.

Abundant and readily accessible supplies of excellent road metal lie close at hand throughout this stretch. Short pieces of splendid roadway in Black Lake village and between Black Lake and Thetford offer evidence as to the sort of highway which can be built of the local materials.

The less important roads are of clay or gravel, and quite good, considering the sparsely settled character of the country.

PURPOSE OF THE INVESTIGATION.

The purpose of this detailed investigation is to solve, if possible, the relation of the different members of the serpentine series to one another and to the intruded sediments; to determine the structural form of the igneous bodies; and by microscopic study of the altered and unaltered differentiates of the igneous complex, to throw more light on the origin of the chromite and asbestos. It is very desirable that all possible assistance be given the mining industry. In 1914, the mines of the region produced about 80 per cent of the world's supply of asbestos; and in 1915, after eight years of non-production, exported nearly 10,000 tons of chromite to the United States to meet demands arising from war conditions.

It is thought that the investigation has reached such a stage that a preliminary statement of some of the results may be of interest.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHY.

General.

That part of the province of Quebec lying south of the river St. Lawrence may be divided, topographically, into two portions along a curving line running from the north end of lake Champlain to Quebec city. To the west of this line is a plain underlain by nearly horizontal strata of Palæozoic age. To the east, and marked off from the plain by a great fault, are the Appalachian highlands. These highlands are a northerly continuation of the Appalachian system of the United States, and extend for 300 miles into Gaspe peninsula.

In the Eastern Townships the highlands consist of three main parallel anticlinal ranges of low hills. These are known as the Sutton, Stoke, and Megantic ranges. The Megantic range lies along the boundary between Quebec and the state of Maine.

In the southern part of the province, the three ranges are narrow and well defined. Farther north, in the Thetford region, the most westerly or Sutton range widens out until it is 15 miles in width, with an altitude in many places along the broad topped ridges of from 1,500 to 2,100 feet. In about the same latitude the central or Stoke Mountain range decreases markedly in height, and to the north of lake St. Francis it loses its identity as a prominent topographical feature.

The igneous rocks of the serpentine series have been intruded into the sedimentary rocks along the eastern flank of the Sutton range throughout the whole of its length from Chaudiere river to beyond the International Boundary,

far into the state of Vermont. At many places, these igneous rocks form abrupt, prominent hills or long, steep-sided ridges, in one case rising to more than 3,000 feet above sea-level.

Local.

The district mapped on the Coleraine sheet lies on the east flank of the Sutton range near its widest part. It includes the foot of the slopes of the range itself, the broken country occupied by the igneous series, and the western edge of the synclinal valley in which upper St. Francis river flows.

The hills of the Sutton range appear at the extreme northwestern corner of the map. On the skyline, these hills appear very regular, unbroken by any sharp peaks or considerable valleys. The slopes are gentle, covered by an evenly distributed mantle of boulder clay, and well wooded. They constitute the only good agricultural land within the map-area, if we except the narrow alluvial flats around Disraeli bay.

A large part of the area is underlain by igneous rocks. These form hills with rugged profiles and steep or precipitous sides, especially where they have been strongly modified by glacial action. The total relief is not great, the elevation varying from 751 feet above sea-level at the surface of Black lake, to 1,820 on Caribou mountain, but a number of cliffs from 100 to 500 feet in height are to be found. On the eastern side of Caribou mountain, just to the north of Kerr hill, is a steep sided cirque. Several smaller, less clearly defined cirques may be made out on other parts of the same mountain.

FUTURE OF THE DISTRICT.

From an agricultural standpoint, this immediate district has little to look forward to. The soil is scant and stony, and much broken up by rocky outcrops. Dairying is now the chief source of revenue for the few settlers and probably will continue to be so.

All valuable timber has been removed long since and, as several fires have swept the district within the last twenty years, no new stand has taken its place. Considerable areas are covered with scrubby birch, poplar, and spruce, or by a dense growth of small alders. Small quantities of pulpwood are still cut from the river bottoms and hillsides which escaped the fires.

The future of the district is bound up with the mining industry, the outstanding feature of which is the nearby asbestos mines of Thetford and Black Lake. These mines produce more than three-fourths of the world's output of this useful mineral and the value of the present annual production is in the neighbourhood of $4,000,000. In the past, several properties have been opened up within the limits of the area under discussion, and have been worked from time to time, and still others are being opened at present. A railway 3 miles in length was built during the past summer from Coleraine station in to a group of claims on Bisby ridge, and already the foundations for a mill have been laid. At the present time, however, there is no production of asbestos from the area mapped.

The present great demand for chromite has resulted in active prospecting over the entire district and several pits are now in operation and producing a fair grade of ore.

GENERAL GEOLOGY.

GENERAL STATEMENT.

Regional.

The three ranges of anticlinal hills which cross the Eastern Townships present cores of highly folded Pre-Cambrian rocks. Flanking this Pre-Cambrian on either side are bands of Cambrian sediments. The synclinal valleys between the ranges are occupied chiefly by Ordovician formations, with smaller overlying patches of Silurian and Devonian, all well exposed, but containing fossils in only a few places.

Three series of igneous rocks are found, the serpentine series, large batholithic intrusions of granite associated with the Megantic anticline, and certain volcanics of widespread distribution at the base of the Cambrian. Of these, only the serpentine series is represented within the map-area.

The rocks of the serpentine series are altered modifications of rocks originally ranging from dunite through peridotite, pyroxenite, and gabbro, to granite and aplite. Outcrops of these occur with but few breaks along the entire length of the southeastern flank of the Sutton range, and as scattered bodies here and there bursting through the Stoke and Megantic anticlines.

Local.

Sedimentary, metamorphic, and igneous rocks are all represented in the area mapped. Roughly speaking, the igneous rocks extend in a broad band from southwest to northeast; but over large areas the surface is so masked by drift that the mapped outcrops of the igneous bodies are very irregular and indefinite.

The igneous mass, when intruded, ranged from dunite, a very basic rock composed almost entirely of olivine, through peridotite, pyroxenite, gabbro, breccia, granite, and aplite. With the possible exception of the granite, all these have been altered more or less and are now very different in appearance and composition from typical, fresh, igneous rocks.

In form, the igneous body is almost certainly a thin laccolith which has been folded and in part eroded.

The differentiation which produced most of the various igneous types is thought to have taken place in the sheet itself after its intrusion. A less extensive and less complete differentiation modified the nature of the magma remaining at the source of supply after the main mass of the magma had been extruded, and later irruptions of this incompletely differentiated material, in the form of gabbro and pyroxenite, shattered and brecciated the previously erupted rocks.

In the sheet-like portion of the igneous mass, the process of differentiation produced a definite arrangement of the resulting types, the most basic dunites being found at the bottom with more and more acid rocks towards the top. Masses of gabbro and pyroxenite of considerable extent are found, but the olivine-rich rock is in relatively small amount.

No true dunite was found. In every case it has been completely altered to serpentine, and it is in serpentine of this origin that the commercially valuable deposits of chromite and asbestos have been found. The peridotites are also largely altered to serpentine, even the pyroxene of the rock having disappeared. Over large areas on Belmina ridge and Caribou mountain, masses of what was originally pure pyroxenite have been serpentinized more or less completely. Valuable mineral deposits have not been found in this serpentine.

The age of the intrusion cannot be determined closely, from the relations observed within the district. It is at least post-Farnham, if the black, pebbly slates are correctly determined as of that age.

The metamorphic rocks occupy a narrow band along the western side of the igneous mass. Areally they are of very subordinate importance.

The sediments are believed to range in age from Pre-Cambrian to Ordovician. Not a single fossil has been found in the area, however, but the formations have been roughly traced into formations of known age and the correlation thus obtained, confirmed by lithologic evidence and structural position, is thought to be very nearly correct.

TABLE OF FORMATIONS.

ERA	PERIOD	FORMATION	CHARACTER
Quaternary	Recent Pleistocene		Stream deposits Glacial deposits.
Unconformity			
Palæozoic	Post-Ordovician	Thetford	Breccia. Granite. Gabbro. Pyroxenite. Serpentine.
		Dyke rocks	Quartz porphyry Diabase. Granite. Pyroxenite.
	Igneous contact		
	Ordovician ?	Farnham ?	Slates, chert.
	Unconformity?		
	Cambrian ?	Sillery ? L'Islet ?	Slates, sandstones. Quartzite, arkose.
Unconformity			
Pre-Cambrian		Bennett	Quartzite.

DETAILED DESCRIPTION OF THE FORMATIONS.

Pre-Cambrian.

Bennett Quartzite. The name Bennett quartzite has been chosen for this member of the sedimentary series on account of its good exposure on the slopes of the hills around Bennett post-office, 3 miles to the north of Belmina post-office, and just off the map.

The Bennett quartzite is of a light whitish grey to a greenish grey colour. Everywhere it has undergone extreme regional metamorphism and is folded and crumpled to such an extent that within a distance of one foot, from five to thirty small plications may be counted. These small crumplings are associated with larger folds a yard or two across, and they in turn with larger and still larger

folds. As might be expected, a high degree of schistosity has been developed and the rock is, nearly everywhere, a pronounced sericite schist. Even the most schistose portions, however, are hard, solid, and compact, a characteristic which serves to distinguish it from a paper thin, fissile phase of the L'Islet quartzite to be described later.

The fissures and cracks which developed in great numbers during the progress of the folding, have been filled subsequently by secondary quartz. The plentiful white stringers of this mineral, varying from a few millimetres to several feet in width, and running in every direction through the schists, are characteristic of this formation.

On account of the high degree of folding and the relatively small size of the individual outcrops, it was not possible to determine, even approximately, the thickness of the formation. It is, almost certainly, many hundreds of feet.

Cambrian.

L'Islet. The L'Islet formation is made up, for the most part, of massive, fine to coarse-grained, light grey to greenish quartzites and quartzose schists. In places the quartzite is almost pure quartz and of a white colour. Here and there, gradations from coarse to fine-grained layers may be clearly made out, thus affording some evidence as to the degree of folding the rocks have undergone. In a very few places the beds have been overturned but for the most part they have been less violently folded, and lie at angles of from a few degrees to as many as eighty-five.

Locally, and notably so in the area bordering on the igneous rocks west of Chalet hill, the L'Islet is much sheared and contains considerable sericite. Stringers of quartz are also numerous and the whole appearance closely resembles that of the Bennett quartzites. In the neighbourhood of the stock-like mass of serpentine east of Breeches lake, still another type appears. Here, the rock is a very fine-grained, friable, paper thin, talcose or quartzitic schist of a flesh to silvery grey colour. Characteristically, however, the L'Islet is a massive rock. Over considerable areas, the presence of small quantities of chlorite gives the quartzite a greenish hue.

No evidence of faulting on anything but a very minor scale is to be found in either the Bennett or L'Islet. The small area of L'Islet quartzite, 1,500 to 2,000 feet long and 1,000 feet wide, lying near the northwest end of East lake, appears to represent a gentle roll in the floor on which the igneous rocks rest. The quartzite itself is very much shattered, especially for 200 feet around the edges of the mass and forms a splendid example of a quartzite breccia. A smaller area of a similar quartzite breccia lies on the northern face of Drouin ridge. In both cases the shattered quartzite is surrounded by breccia.

The distinction between the Bennett and L'Islet formations has been made on the basis of lithology and metamorphism. As compared with the Bennett, the L'Islet is less sericitic, less crumpled and folded, less schistose, and contains much less secondary quartz. The microscopic study of the rocks, which has not yet been undertaken, will possibly give further aid in distinguishing them. Actual contact between the two has not yet been observed in this district.

Sillery. The Sillery formation occupies an inconsiderable area within the map limits. In the neighbourhood of Stenson and on the hills 2 miles east of Belmina post-office, it is found in several, narrow, elongated bands, infolded with the L'Islet quartzites. Two small patches appear along the borders of the band of breccia north of East lake; a third in the breccia on Bisby ridge; and still others, too small to be mapped, in the breccia east of Coleraine village and on the west side of Oak hill.

The Sillery formation, as known within this area, is composed of reddish, purplish, and greenish grey slates with intercalated bands and lenses of coarse red or grey arkosic sandstone. The variations in colour are due to the presence of more or less hematite in very minute grains. At its type locality in Sillery cove on the St. Lawrence near Quebec city, it appears as shales and sandstones, but in the neighbourhood of the igneous intrusions the shales have been changed to slates. Unfortunately, the folding has been so intense that no commercially valuable slate deposits have resulted.

It was quite impossible to determine even the approximate thickness of the Sillery present. In places where the slates were observed in contact with the L'Islet beneath, no evidences of unconformity were seen but no positive conclusion could be arrived at.

It may be noted that pyrite crystals of cubic form, up to an inch in dimensions, are quite commonly found in the sandy and arkosic phases of the Sillery.

The tentative correlation of these few slate outcrops with the Sillery of Quebec rests entirely on the colour, lithological character, and apparent stratigraphic position of the beds. Reddish slates, correlated with the Sillery, do occur between Thetford and Quebec, and it is thought that these slates around Coleraine represent a Cambrian deposition farther to the south than had been noted previously.

Ordovician.

Farnham. The Farnham is much more widespread than the Sillery. It occupies a basin of considerable size between Lemay hill and Belmina ridge and underlies all the area lying to the southeast of Bisby ridge. A small patch borders the breccia to the east of Coleraine, but its extent could not be determined on account of the drift covering beneath which it disappears.

The Farnham is believed to be of Ordovician age and is the youngest of the consolidated sediments in the map-area. The formation, as represented, is made up of black, rusty black, or dark green argillaceous slates. The rocks are soft, intimately folded, and much shattered. In no instance are they as hard and compact as the underlying Sillery. On exposed surfaces they are invariably so badly disintegrated as to make any attempt at determining the bedding useless. The rapid disintegration is due to the abundance of pyrite. This pyrite appears, in a fresher piece of rock, as partly weathered, rusty cubes, 4 to 5 mm. in size, and so abundant in places that, on a specimen as large as the palm of the hand, as many as seventy cubes have been counted.

In the bed of Pine river, where erosion has cut most deeply into the Farnham, the slate is of a pebbly character. In places the pebbles are so numerous that the rock may be said to approach a conglomerate, but as a rule they are less plentiful and form not more than 10 or 15 per cent of the rock mass. They are well rounded and water worn. Greenstone and quartzite pebbles are most numerous, with a few of a slate-like rock, all lying embedded in a matrix of the black, argillaceous slate. It is largely on the strength of this striking conglomeratic phase that the black slates of the region are correlated as Farnham.

The thickness of the Farnham was not ascertained but it is probably several hundreds of feet.

The complete absence of fossils over the entire region makes the problem of correlation one of lithology and areal extension and leaves it, at best, in an unsatisfactory state. Thirty miles to the south, fossils of Silurian and Devonian age have been found. An attempt to tie up these known horizons with the beds around Thetford and Black Lake may establish their age with more certainty.

Pleistocene.

Pleistocene deposits are found, here and there, over most of the area. To the east and southeast of Coleraine the mantle of glacial drift is continuous and no rocky outcrops were discovered. Where the drift is so thick and so continuous as completely to hide the character of the underlying rock, this fact has been shown on the areal map. No attempt was made to interpolate geologic boundaries across some of the larger drift covered areas.

The moraine itself is stony but rather evenly distributed over the slopes. The tops of most of the igneous hills are relatively bare, except for scattered erratics.

Around the margin of Disraeli bay, there are a few hundred acres of flat-lying alluvial and stream deposits.

Igneous Rocks.

The rocks of the Thetford series are, for the most part, basic, with minor amounts of granite and aplite. These latter appeared as the last phases of the differentiation which produced the different types.

For purposes of mapping, six phases have been macroscopically distinguished, serpentine, serpentinized pyroxenite and peridotite, pyroxenite, gabbro, breccia, and granite. The microscopical examination of these rocks has not yet advanced sufficiently far to afford much information but it may be worth while to note the approximate mineralogical composition on which the names of the basic members of the series are based.

Pyroxene 99 per cent	pyroxenite.
Pyroxene with 1 to 5 per cent olivine	olivine-bearing pyroxenite.
Pyroxene with 5 to 95 per cent olivine	peridotite.
Olivine 95 to 100 per cent	dunite.

Dunite and Serpentine. Under the microscope, the rocks mapped as serpentine show little or nothing but this mineral.

The serpentine appears in a number of places but is nowhere of great areal extent. The largest mass lies at the foot of Caribou mountain on the eastern and southern sides. The valley between Caribou and Oak hill, as well as part of the gravelly apron between Caribou mountain and the triple crests on the country line to the south, are probably underlain by serpentine.

A band of serpentine may be traced without interruption for $2\frac{3}{4}$ miles from the hill 1 mile southwest of Coleraine to a point south of East lake. For $1\frac{1}{2}$ miles beyond, drift covers the probable contact, but serpentine again appears near the northeast corner of Breeches lake. The band cuts across the point between the legs of the breeches, appears on the small island in the lake, and again on the flat to the southwest of Chalet hill. At the southern end of the same lake a large mass of serpentine and pyroxenite begins and extends beyond the map limits.

Five small patches or dyke-like masses of serpentine are associated with the more easterly band of L'Islet quartzite. The most southerly one lies to the south of the Disraeli-Breeches Lake road; three others to the east of the railway near Carineault hill; the fifth as a small drift bounded outcrop 1 mile southeast of Coleraine. Several scattered and irregular outcrops are to be found along Bisby ridge.

On fresh fracture surfaces, massive serpentine varies from dark olive green to dull greenish black in colour. Slickensided surfaces are a much lighter, grass green colour, and highly polished. On well weathered surfaces the serpentine is of a dirty cream colour, locally tinged with red. Only very rarely is pure serpentine of a distinctly red hue.

The rock is soft and, in most places, considerably fractured. This serpentine has resulted from the alteration of a pure dunite. In many places, the olivine has disappeared completely but the irregular network of minute crystals of chromite and magnetite, or of veinlets of asbestos lying in the serpentine, points to its derivation from olivine. Evidences of a few scattered crystals of pyroxene, now likewise altered to serpentine, can be made out here and there.

The alteration from olivine to serpentine entails a very considerable increase in volume. The effects of this expansion are very evident in the serpentine which is shattered, sheared, and slickensided over large areas. It is in these zones of shattered rock that most of the long-fibre asbestos is found.

The serpentinization of the basic rocks is, primarily, a question of hydration. As such it has often been considered as having proceeded from the surface downward. If this is the case, the alteration has proceeded with extraordinary completeness to very considerable depths. It is hoped that a careful study of a number of specimens taken at different depths from the present surface, and through a considerable range, may throw some light on this point. The mineralogical association in a number of mines also points strongly to thermal waters as the cause of the serpentinization. A detailed study of the mineralogy of the region is at present nearing completion and may solve this problem.

The serpentine, in common with all the other members of the Thetford series, is of igneous origin. Wherever it is associated with them, it is found to lie either stratigraphically below the other members or to be surrounded by them. The first condition prevails near East lake; the second on Brousseau hill and on Belmina ridge.

Partly Serpentinized Peridotite and Pyroxenite. This type does not form so sharply defined a petrographic phase as the one just discussed. It outcrops in large masses, on Caribou mountain, and Belmina ridge, and less extensively on the east side of Oak hill, on Brousseau hill, and to the north of Bisby ridge.

Bearing in mind the mineral composition of peridotite, as previously defined, it will be seen that if we except dunite this phase will embrace all serpentinized rocks originally containing more than 5 per cent of olivine. As a matter of fact, it includes the largest masses of serpentinized rock in the region, and, since the original rocks varied considerably in mineral content, their altered equivalents vary somewhat in appearance.

It will be convenient to consider the rock of Belmina ridge and that of the area north of Bisby ridge together. In both of these areas much of the original rock was a peridotite with a fairly high olivine content. The rock on Caribou mountain and on Oak hill, on the other hand, was relatively much richer in pyroxene. Both types have since been partly serpentinized and they weather to a brick red colour.

On exposed surfaces, the serpentines of Belmina ridge have a rusty red weathered zone varying from paper thin to as much as one-quarter inch in thickness. On fresh surfaces, massive phases are of a deep olive green to greenish black hue; slickensided surfaces are polished and of a brilliant light green; small masses of minutely fractured and sheared serpentine, found near the south end of the ridge, are of a purplish tint.

The outlines of altered pyroxene crystals may be seen on any freshly broken surface, scattered here and there in the duller, more granular olivine of the peridotitic phases, more plentifully in the pyroxenic phases, and in rarer instances making up practically the whole mass of the rock.

Olivine rich peridotites appear here and there on the ridge, surrounded by rock with a much higher content of pyroxene. The small oval outcrop near the school-house on the Belmina road is quite rich in olivine; so also is the rock in the vicinity of the prospect pits at the north end of Belmina and around the larger

quarries at the southern end of the ridge. These quarries were operated for some months and a considerable quantity of asbestos was obtained from a shattered zone in a pocket of peridotite. The peridotite is surrounded by rock much richer in pyroxene and devoid of asbestos fibre.

The serpentinized rock of Caribou mountain and of Oak hill originally was composed almost exclusively of pyroxene. It too weathers to a rusty brick red colour but serpentinization has nowhere proceeded to an important extent. On fresh surfaces, the rock is of an olive green colour and, to the unaided eye, appears to consist entirely of pyroxene. The crystal faces vary from a few millimetres to as much as 2 or 3 inches in length. The rock is exceedingly hard and tough and resists erosion better than the softer members of the series already described.

Under the microscope, it is seen that serpentinization has begun here and there between the grains of pyroxene, and along the cleavage cracks. Thin films of serpentine mark its progress.

The relations between this more acid phase and the dunites are well shown on Oak hill. Along the contact between the two types, especially toward the southern end of the hill, the coarsely crystalline, rough, hackly, pyroxenitic phase has intruded and brecciated the finer-grained olivine rock. Pyroxene crystals as much as half an inch in length are plentiful in small, ribbon-like dykes, 1 or 2 inches across. The dunite appears as globular, ellipsoidal, or irregular masses varying from the size of an egg to the size of the human head, and surrounded by a network of small pyroxenite dykes. The brecciated zone is from 30 to 40 feet wide. Stringers of pyroxenite cut through the dunite here and there over most of its extent, but noticeable brecciation occurs only along the border.

"Nail head" structure, so called by Dresser, is frequently found in these rocks. On exposed surfaces, the olivine and serpentine wear away more rapidly than the tougher pyroxene, with the result that the grains of the latter mineral stand out on the surface and give the rock a nubbly appearance.

Pyroxenite. Pyroxenite is of rather wide distribution. A U-shaped aureole of this rock is found at the southern end of Belmina ridge; it appears as a narrow band paralleling the serpentine from Breeches lake to near Coleraine; a large mass forms the southern and eastern slopes of Oak hill, and the small outcrop just north of Chrome siding probably indicates a continuation of this body; a broad band cuts across the smaller hill, 1 mile northwest of Brousseau hill; finally, much of Bisby ridge is composed of pyroxenite.

This rock differs from the serpentinized pyroxenite just described in the fact that it is essentially fresh and unaltered. On exposed surfaces, it is of a greyish green colour instead of the rusty red characterictic of the previous type. It is exceedingly hard and tough and, for the most part, coarsely crystalline, crystal faces up to 2 or 3 inches in length being common. On freshly broken surfaces it is of a bronze green to dark green colour.

This pyroxenite is younger than any of the rock types just described. In the brecciated zone of peridotite on Oak hill, previously spoken of, stringers of coarsely crystalline, greenish grey pyroxenite may be seen cutting across both the fine-grained olivine rocks and the reddish weathering pyroxenic dykes. Thus, in the hill three eruptive types are evident. The intrusions followed rapidly one after the other, each succeeding magma more acid than its predecessor.

Gabbro. Gabbro occupies a considerable area in the centre of the sheet between Breeches lake and East lake. A narrow band runs at least part way along the eastern flank of Belmina ridge. Another band parallels the serpentine from near East lake to Coleraine and reappears at the foot of Oak hill and on the large hill to the northeast of the village. It is probable that the valley, through which the road and railway pass from Coleraine to Chrome siding and Black lake, is under-

lain by gabbro but this cannot be certainly known on account of the heavy covering of drift. A small oval outcrop in the midst of the alluvial flat south of Caribou mountain may indicate a much larger body of gabbro whose extent cannot be determined. Finally, this rock is exposed over a small area on the south side of the ridge northwest of Brousseau hill.

In previous descriptions of this general region, considerable masses of diabase have been mentioned. No specimens were found by the writer which showed a diabasic texture in the hand specimens nor have any of the few slides hurriedly examined given evidence of it. More extended microscopic work may demonstrate the presence of diabase in considerable masses, but until such proof is forthcoming it has been thought better to class all the pyroxene-feldspar rock of the area under the head of gabbro.

The gabbro varies widely in appearance. A few small masses were found with grains of feldspar and pyroxene up to 1 cm. in length. In such a rock, the feldspar is dark grey and the pyroxene green. The rock itself is very hard and tough and comparatively fresh.

Much of the gabbro is only moderately coarse grained, the individual grains a few millimetres in size but quite easily distinguished by the unaided eye. The rock which previously has been called diabase is of the same mineral composition, but it is so fine grained that pyroxene and feldspar individuals are rarely distinguishable in the hand specimen. This fine-grained phase is of a greyish green colour with occasional grey feldspar crystals or stringers of yellow-green epidote. The microscopic study of this and the succeeding types has hardly been well begun. The presence of considerable quantities of epidote, however, indicates that extensive alteration has taken place.

The relation of the gabbro to the more basic phases is clearly shown on Lemay hill. It will be seen that the major part of this hill is mapped as gabbro but much of the mass assumes almost the nature of a breccia. A few bodies of pyroxenite of considerable size and many smaller fragments are surrounded by a matrix of fine-grained gabbro. In some cases these fragments may have been torn loose from the previously erupted pyroxenite. In other cases, the partially cooled pyroxenite seems to have been fractured and the crevices filled by the gabbroic magma.

The gabbro itself was not all intruded at one time. Older, coarse-grained phases have been shattered and the fragments are now embedded in finer-grained younger types. The intrusion of the gabbro was probably a long drawn out process, one flood of material following another and breaking up the rocks already partly solidified. That the interval between intrusion became longer and longer may be inferred from the fact that the successive intrusive bodies of gabbro are progressively finer grained. This indicates more rapid cooling, due to the lower temperature of the surrounding rocks.

The fine-grained type of gabbro passes, almost imperceptibly, into what has been mapped as "breccia." This gradation and the accompanying difficulty of differentiating between the two rocks is especially marked where much epidote is present, where alteration has proceeded to a considerable extent, or where fragments of the other members of the igneous series become sufficiently numerous to make the rock resemble a breccia. It may be noted that in the areas mapped as gabbro, although angular fragments of coarse-grained gabbro and of pyroxenite do occur plentifully in places, no fragments of the sedimentary rocks have been found. In the "breccia" on the other hand, fragments of slate and quartzite are numerous and widespread.

Breccia. Breccia outcrops in a band extending, with but two breaks, from Belmina ridge to the hill east of Coleraine village. A second interrupted band runs from the triple peaks on the county line northeastward across Oak hill.

The most typical area lies around and to the north of Brousseau hill. Two small masses appear to the west of Disraeli bay, at the contact between the Farnham and the L'Islet.

The term "breccia" includes a number of rock types, but all of these, collectively, are regarded as forming the contact phase of the igneous rocks of the Thetford series. The particular character of the breccia in any one locality depends on the condition of intrusion, the nature of the immediately overlying and underlying sediments, the proximity of the intrusive mass to the surface at the time of intrusion, and the volume of magma intruded. These points can be best brought out by a consideration of the most conspicuous modifications.

The different types grade into one another in all directions, in some cases gradually, in others with more sharply defined boundaries. No attempt was made to do more than record the locality where each type could be best seen.

The more northerly of the two bodies of breccia lying to the west of Disraeli bay shows the best example of pillow lava structure within the area. Similar pillows may be seen at a number of places in the mass, on, and to the north of Bisby ridge.

Within short distances, the pillow lavas grade into an amygdaloidal rock with no traces of ellipsoidal structure, the amygdules filled with carbonates and quartz. Or they may grade into a soft, friable, porous rock, approximating to pumice in character.

It seems certain from the close association of these lavas with the other igneous rocks, and from the fact that they always appear in a definite stratigraphical position with relation to them, that they form part of the Thetford series. The ellipsoidal and pumiceous character of certain portions of the breccia would indicate that, in these places at least, the intrusion must have been very close to the surface if it did not actually reach it. The fact that the band of breccia appearing on the Breeches Lake road at the contact of the slates and quartzites, is interrupted, as well as the finding of ellipsoidal structure in this small mass of igneous rock, suggests that it may represent the extreme edge of a laccolithic sheet and that, at this point, the ellipsoids indicate the farthest outpushings of the lavas under their covering of Farnham slates.

Over considerable areas on Bisby ridge and to the west of East lake the breccia is of a different character, which, for convenience in field work, was called the "bomb" type. The "bombs" are small masses, rarely over 1 foot in diameter, of a whitish weathering, porous rock. On exposed surfaces, the contents have been dissolved out from the amygdules, but in the centre of the "bombs" the vesicles are still full. The paste in which these lumps lie is of a greenish brown colour, more or less ropy in appearance, and seems to have flowed around them. Where plentiful, the nodules make up as much as 50 per cent of the rock but over considerable areas they are very scarce. Much of the rock in which nodules are absent, or nearly so, has been called diabase in earlier reports. It has been greatly altered and is now made up almost entirely of secondary minerals. Carbonates, epidote, chlorite, and talc are especially abundant.

In the band of breccia crossing the west side of Oak hill, there are numerous fragments of a very dense, hard, green, glassy, rock as well as pumiceous fragments, lying in a pasty, ropy, fine-grained matrix which contains much epidote. The general appearance of this rock suggests an effusive origin and it is possible that this and the "bomb" type on Bisby ridge may represent an effusive phase of the igneous action, not previously recognized in the region. Until the microscopic work has been completed, nothing definite can be stated.

On the small hill just southeast of Coleraine village, an exposure of good, typical breccia is to be seen. The molten magma here intruded a body of red slate which, as a result, was much shattered, fused, and baked. Fragments from

a few inches to several feet, across as well as long bands and stringers of red slate, are embedded in a paste of igneous rock. On the same hill there is an exposure of breccia in which fragments of nearly every rock in the neighbourhood can be found. Quartzite, red slate, grey slate, pyroxenite, gabbro, and granite are all present in pieces from a few inches across to blocks 6 feet long and 2 feet wide. The intruding magma tore off and carried with it masses of all rocks with which it came in contact. Another splendid example of a similarly brecciated mass of sediments and basic igneous rocks is to be found on the most western of the triple peaks on the county line. On the northern face of Drouin ridge, the magma carried with it an irregular mass of quartzite more than 100 feet long. This mass was completely shattered into blocks a foot or more square and later pressed together and recemented without the introduction of any considerable amount of igneous material.

This truly brecciated phase of the breccia appears to represent the contact between the intrusives and the enclosing sediments. Over most of the area it has been removed by erosive agencies and now appears only where it has been infolded or around the borders of the outcrops of the overlying Farnham slates.

Granite. In areal extent, granite is one of the least important rocks of the series. Small outcrops are located near the outlet of Breeches lake; on the north shore of East lake; on Lemay hill; at the east end of Drouin ridge; between Belmina ridge and Caribou mountain; and on Bisby ridge. The only large mass of granite lies just north of Bisby ridge.

Granite, in dykes and larger masses, cuts all the other important igneous rocks of the area. It is itself cut, here and there, by narrow dykes of a fine-grained, dense, greyish green rock, probably diabase. These latter dykes are in sharp contrast to the coarse-grained granite and were intruded into a cold rock.

Narrow dykes, a foot or two wide, of an almost pure feldspar rock, occur here and there. They are quite devoid of any traces of ferromagnesian mineral but often show considerable quantities of quartz. These dykes represent the extreme acid end of the series. The granite is, for the most part, quite fresh, but in many cases these feldspar dykes are so badly decomposed that the rock will crumble between the fingers into a mass of loose quartz grains and partly kaolinized orthoclase.

Narrow aplitic dykes are also numerous. The material is so fine grained that only rarely can any idea of the constituents be obtained from the hand specimen.

Mode of Origin. The best section of the igneous rocks to be found is on Drouin ridge and has already been described by Dresser in Memoir 22, G.S.C., page 49. Within a distance of 1,500 feet north and south across the ridge, all the important members of the igneous series are well exposed. Starting from the foot of the cliff and proceeding northward in direction and upward in the stratigraphic column, the rocks are met in the following order: serpentine (serpentinized dunite), pyroxenite, coarse gabbro, fine-grained gabbro, breccia, granite. The serpentine rests on quartzites dipping to the north at about 65 degrees. The breccia is overlain by slates dipping in the same direction at about the same angle. Thus, at this point, the igneous body is about 600 feet in thickness. The boundaries between the adjacent phases are nowhere sharp. One rock grades into the next without any break but so rapidly that it is possible in most places to locate an approximate petrographical boundary within 20 or 25 feet.

A similar, though less sharply defined and clearly exposed arrangement of the different igneous phases, may be seen at a number of places between Drouin ridge and Breeches lake, and again on the ridge to the northwest of Brousseau hill.

The various members making up this sheet appear to have been formed from a common basic magma by a differentiation in place after intrusion. This

differentiation may be theoretically explained by fractional crystallization and settling. The olivine crystallized first and would settle to the bottom of the molten mass, forming dunite. Pyroxene then began to crystallize and, mixing with the last settling crystals of olivine, would form peridotites of progressively lower olivine content. When olivine failed entirely, pyroxenite would result. After feldspar began to appear, gabbro would be formed in large masses, becoming finer and finer grained toward the surface. If the several rock types were the product of a number of distinct, successive irruptions, injected one upon the other, we would expect to find, in some places at least, sharp boundaries between the distinct sheets which would necessarily result from this mode of injection. No such boundaries were seen.

On the other hand, there is much evidence that the whole body of igneous rock was not intruded at one time. Dunite was not seen to cut any of the other members of the igneous series but pyroxenite dykes intrude the dunites on Oak hill and elsewhere; gabbro intrusions brecciate previously irrupted pyroxenite and gabbro; and dykes of granite and aplite cut all the other phases. On Lemay hill and on the big hill east of Coleraine towards the power line, coarse-grained gabbros and pyroxenites are shattered and the fragments united into a sort of breccia by a finer-grained gabbro.

A few fine-grained to glassy dykes of a hard, diabasic rock cut all the other members of the igneous series.

The numerous dykes and the brecciation of some of the igneous rocks point to successive intrusions. Since the material of all the dykes except the aplites, and of the matrix of the breccia is commonly well crystallized, it is probable that the secondary intrusions took place during the same general period of igneous activity and while the first intruded rocks were still somewhat hot.

In the opinion of the writer, the initial phase of the igneous action was the most extensive. A laccolithic sheet of very considerable size and thickness and of basic composition was intruded into the sediments and differentiated in place. After the main intrusion had been completed the material remaining in the magma basin must have been of a more acid character since subsequent irruptions did not produce the most basic end member of the series. While the main sheet was cooling and differentiating in place, the dregs of the magma in the magma basin were presumably undergoing a similar, if less complete process. Subsequent irruptions produced the pyroxenite dykes and subordinate quantities of fine-grained gabbro which, in many places, burst through and brecciated the main sheet. The last extrusions from the basin, represented by granite and aplite, are of small volume and represent the close of the igneous period.

A later recrudescence of igneous activity of very minor importance is represented by a few fine-grained diabase dykes.

Relations. As shown within this area, the relations of the different igneous types to one another are fairly definite, but no sharp physical boundaries can be drawn between them as they grade into one another. In many places, the dunite lies upon a floor of L'Islet quartzite and grades upward into peridotite, pyroxenite, gabbro, and breccia, the latter in intrusive contact with the overlying slates. No exception to the above order in the sequence of gradations was observed where two or more members of the series were found, but all types are not represented wherever the igneous rocks appear. Thus, dunite is not present on Belmina ridge; and to the west of Disraeli bay along the southeastern boundary of the igneous outcrops, the entire series is represented solely by some ellipsoidal lavas and a few granitic dykes.

General Structure. The area lies on the west flank of a broad syncline whose bounding anticlines are the Sutton and Megantic hills. The youngest consolidated rocks occurring in this major basin are Devonian and these, as well as all

the older formations, are intensely folded. The deformation which is general throughout the whole basin is abundantly evident in the small section of it under discussion.

The strike of the more important structural features is northeast-southwest. The broad band of quartzite between Disraeli bay and Breeches lake represents an anticline pitching to the northeast. The younger slates in the valley of Pine river to the north of East lake, lie in a shallow synclinal basin which dies out toward Breeches lake. The quartzite along the western border and the slates in the southeastern corner of the map dip to the southeast.

The igneous rocks form part of a folded and eroded laccolithic sheet, injected above the L'Islet and below the Sillery, both of which are of Cambrian age. Along the flanks of the anticline previously mentioned, they outcrop in two bands across the central portion of the sheet. To the southeast of Bisby ridge, the intrusive dips beneath the Farnham slates and probably thins out rapidly, judging from the character of the outcrops to the west of Disraeli bay.

No evidence has been found to indicate the probable extension of the sheet to the westward beyond its present boundaries. The fact that the igneous masses along the contact between the intrusive and the quartzites are of much greater volume than are found elsewhere in the serpentine belt, suggests that the westward extension may have been of important size.

Metamorphic Rocks.

A narrow band of metamorphic rock borders the igneous rocks along their western boundary and runs from the northwest arm of Breeches lake along the west side of Belmina ridge. A second small outcrop lies close to the northern boundary of the sheet, just west of Caribou mountain.

The microscope shows this rock to be a hornblende schist, derived in part from the neighbouring sediments, in part by alteration of the gabbro. Hornblend eclogite occurs in considerable masses.

HISTORICAL GEOLOGY.

After the deposition of the Bennett quartzite and before the L'Islet was laid down, the rocks underwent intense folding. This is shown by the greater deformation of the older quartzite.

During Cambrian time, a period of sedimentation followed and the L'Islet and Sillery were deposited, presumably conformably one upon the other.

At the close of the Cambrian, the land emerged and a period of erosion followed.

Following re-submergence, the Farnham slates were laid down. The unconformity is marked by the basal, conglomeratic slates of this formation. Probably Silurian and Devonian rocks were deposited in parts of the area. Within the map limits, however, these have been entirely removed, if ever present.

Emergence was accompanied or followed by the intrusion of the Thetford series. Then followed gentle folding of all the rocks including the igneous.

So far as known, subaerial erosion went on from later Palæozoic to Pleistocene times. In the Pleistocene, glaciation was general and the mantle of till and alluvium was laid down.

Post-Pleistocene erosion has added a few minor features to the topography and given it its present expression.

ECONOMIC GEOLOGY.

The only minerals of economic importance found within the map limits are asbestos, chromite, and copper. The first two have been mined but there is no

production of asbestos at present. A small annual tonnage of chromite comes from a number of prospects on Caribou mountain and Belmina ridge.

ASBESTOS.

On a number of occasions within the past fifteen years, attempts have been made to produce asbestos from a number of deposits within the area under discussion. Optimistic promoters installed mills before thoroughly testing their ground and in each case the property was shortly abandoned, to the detriment not only of the investors but of the mining industry as a whole. A large mill, a railway, and a cable way were built around the pits at the south end of Belmina mountain. This plant operated for a few months, extracted a few thousand bags of asbestos, and then shut down. It is now falling into decay. Another mill was erected beside the serpentine outcrop 1 mile east of Breeches lake. Apparently the sole reason for building a mill was the presence of the serpentine, as no asbestos fibre is to be seen in the rock. The mill never turned a wheel and, after standing for a number of years, was sold for a few hundred dollars, and transported to a new prospect on Bisby ridge, half a mile east of the map limits. During the past summer a railway 3 miles long was built from Coleraine station to this new prospect which gives little evidence of being more profitable than its unfortunate predecessors.

On the whole, no evidence was seen which gives promise of important deposits of high grade asbestos being found in the Coleraine sheet. The rich deposits of Thetford and Black Lake, a few miles to the north, occur in peridotites and dunites, the most basic members of the igneous series. Within the map-area, no large masses of these basic members were found. They do occur in bands and small masses, and in such places minor amounts of good asbestos have been discovered, but the quantity of this high grade material is so small and the quality of the short fibre found here and there throughout the more acid rocks is so poor, that competition with the fully established mines of Thetford and Black Lake is not possible.

The demand for asbestos is very brisk at present, the price of No. 1 Crude having been as high as $600 per ton recently. Further, the uses to which asbestos is being put are multiplying so rapidly that the demand will almost certainly keep abreast of, if it does not outdistance the supply. Over 80 per cent of the production goes to the United States.

All the asbestos of the region is of the chrysotile variety, essentially the same in chemical composition as the serpentine in which it occurs. Both cross fibre and slip fibre are found, the cross fibre in the serpentinized dunites and olivine rich peridotites, the slip fibre more commonly in the serpentinized pyroxenites and acid peridotites.

CHROMITE.

The chromite occurs in disseminated grains and masses in the more basic phases of the intrusion. Only rarely is it in minable quantities. Many small prospect pits have been opened up but in nearly all cases the amount of chromite present is so small that the rock cannot be considered an ore. At present there is a small production from three or four little quarries on Caribou mountain and on Belmina ridge. The principal producer is situated in the band of serpentine at the foot of Caribou mountain, on the south side, just west of the Ireland-Coleraine township line. It is known as the Bennett pit and is operated by Mr. Bennett of Thetford. It produces a few tons of fairly good ore every day. The output of the other pits is negligible, being only a car or so per month.

At present war prices, chromite which cannot be worked under normal conditions, can be mined and sold at a profit. During the past year, a small concentrating plant was put in operation near Black Lake and is treating a considerable volume of low grade ores from the mines to the east and southeast of Black lake. Transportation to this plant from the pits within the map-area would be very expensive, however, and the quantity of ore obtainable as well as its quality, make it improbable that the life of the few small pits in operation will survive the war time demand at high prices which makes the hand cobbing of the ore taken from small lenses a profitable occupation at present.

COPPER.

During 1915, a small pit and a couple of diamond drill holes were sunk in the mass of a diabase dyke which cuts the breccia close to the end of the side road, one quarter mile northwest of Brousseau hill. No body of ore was found. Small quantities of chalcopyrite, pyrrhotite, bornite, and arsenopyrite appeared in a silicified shatter zone in the dyke and led the prospectors to hope that a considerable body of ore might be found. No such hopes are now entertained.

A similar small showing of chalcopyrite is to be found on Pine river in the midst of the area of gabbro to the northeast of Chalet hill. A little trenching was done but nothing encouraging was encountered.

A few flakes of molybdenite were seen in the granite and serpentine along the contact between these two rocks, on the east slope of the little ridge, northwest of Brousseau hill.

NORTHEASTERN PENINSULA OF LABRADOR.

(*A. P. Coleman.*)

INTRODUCTION.

Northeastern Labrador has been more or less visited for 150 years and a number of brief trips have been made to its shores by geologists and explorers, but practically nothing has been known of its geology except at a few points on the coast. The reports available show that the region is of great interest as regards Pre-Cambrian and Pleistocene geology, that it includes formations elsewhere important for their economic minerals, and that the most impressive mountains in eastern America occur near cape Chidley.

During the summers of 1915 and 1916 field work was carried on in this region, resulting in the mapping of the topography and geology of portions of the Torngat mountains and of various bays and islands along the coast.

The region is easily accessible from the sea, and is south of latitude 60°30[1], but its climate is practically Arctic because of the cold current flowing past its shores laden with ice from Davis strait and Greenland, and there are no permanent settlements beyond a few families of Eskimo north of Hebron, a Moravian mission station in latitude 58 degrees. This is in striking contrast with conditions in southern Norway and Scotland in the same latitude across the Atlantic. The climate forbids agriculture and at present the chief resources of the region are to be found in the fish and mammals of the sea. The presence of large areas of rocks like the Grenville and Huronian of Ontario and Quebec suggests, however, that mineral deposits of importance may be found in the future. Graphite and iron pyrites are known to exist in considerable amounts.

PHYSIOGRAPHY.

Though portions of the south and west sides of the peninsula have the usual Pre-Cambrian topography of rolling hills separated by irregular valleys, most of northeastern Labrador consists of table-land and mountains. Originally the region was a peneplain, but this was elevated along the eastern side before the Pleistocene and now forms a table-land rising in places 4,000 or 5,000 feet above the sea, though still preserving the original rolling surface. The lofty edge of the table-land towards the Atlantic suffered great erosion by valley glaciers during the ice age and was thus gnawed into very rugged and alpine looking mountains, some of which reach 5,500 feet. The valleys are deep and U-shaped and many of them are floored by the sea and form typical fiords. Owing to the complete lack of forest trees and the comparatively small amount of lower growths, except in sheltered valleys, the region presents a very grim and inhospitable appearance.

The valleys and cirques carved in the table-land are occupied by innumerable lakes and are drained by rivers having many falls, sometimes of hundreds of feet, where hanging valleys come out upon a main valley or fiord. Many of the cirques among the higher mountains within 20 or 25 miles of the sea are occupied by small glaciers, and permanent snow fields or heavy snow banks are found in many places on or among the mountains and even in lower ground as far south as Hopedale in latitude 55 degrees. These are formed probably where drifting snows lodge in quantity, since the total amount of precipitation does not seem to be very heavy.

GENERAL GEOLOGY.

The region is usually spoken of as Laurentian, by writers who mention the geology, but it has been found that large areas consist of sedimentary rocks resembling the Grenville series of Ontario and Quebec. In addition there are later sediments and eruptives in at least two areas, which may be the equivalent of the Huronian, Animikie, or Keweenawan, though without more certain evidence of their age it seems better to give them local names.

From the later Pre-Cambrian to the Pleistocene is a blank. Pleistocene deposits are by no means universally found, since the table-lands and mountains rising above 2,000 or 2,500 feet show no drift deposits, their surface consisting of rolling fields of angular rock fragments mostly *in situ*. Moraines and often also boulder clay are found in most of the valleys, and river deposits often occupy the floor of the valleys, while beach materials occur on terraces in almost every sheltered cove along the coast.

The classification adopted is as follows:

Table of Formations.

Recent	River gravels and beach deposits.
Pleistocene	Marine terraces. Glacial deposits.
	Great unconformity.
Pre-Cambrian	Mugford series Ramah series. *Great unconformity.* Basic dykes probably older than the Ramah series. Equivalents of the Sudbury or Timiskaming series? Grenville series. Keewatin? Laurentian—granites and gneisses in eruptive contact with the Grenville.

ECONOMIC GEOLOGY.

The only well known economic mineral of Labrador is the variety of plagioclase called labradorite, sometimes having a magnificent play of colour, usually blue but often including flashes of green, orange, yellow, and red. The source of the "precious" labradorite is an anorthosite area including islands and part of the coast near Nain. The material has been quarried and is kept in stock by certain mineral dealers. It is somewhat used as a minor gem stone.

The only mine known to have been opened in Labrador is one for pyrites at Rowsell harbour south of Nakvak, but this was not worked extensively.

The considerable areas of Ramah and Mugford rocks, suggesting the Huronian and Animikie or Keweenawan of the Great Lakes, may be looked on as promising regions for the prospector. Pyrite occurs in them and copper ore has been reported. The widely spread Grenville series, often charged with sulphides and in one large area containing much graphite, seems worthy of attention from prospectors. Graphitic gneiss is known to reach 45 miles inland near Nakvak fiord.

Soapstone is found in several places and was of importance to the Eskimo for the making of lamps and pots before the coming of the white man; and rocks suitable for building or ornamental stone are not infrequent, but under present conditions these materials are without value.

TUNGSTEN DEPOSITS OF NEW BRUNSWICK AND NOVA SCOTIA.[1]

(*Charles Camsell.*)

The importance of tungsten in the steel industry and the extraordinary demand for the metal in connexion with war munitions made it necessary to investigate any tungsten deposits that were worth mining. These investigations were made at the request of the Canadian Munitions Resources Commission, and covered certain deposits in New Brunswick and Nova Scotia.

BURNT HILL TUNGSTEN MINE.

The Burnt Hill tungsten deposit is situated in York county, New Brunswick, on Southwest Miramichi river near Burnt Hill brook (Figure 9). It may be reached either from Boiestown on the Intercolonial railway by a 30-mile canoe journey upstream, or else from Maple Grove on the National Transcontinental railway over a very bad bush road 18 miles in length.

The deposit outcrops as a quartz vein on the slope of the valley 170 feet above the river and about 2,000 feet from it. The slope rises at an angle of 28 degrees up to a summit 530 feet above the river. Its sides are thickly wooded and heavily covered with drift so that outcrops of the bedrock are rare.

The country rocks in which the deposits lie are argillites which are intruded by a granite batholith outcropping on the north side of the river about three-fourths of a mile away. The argillites strike about north 65 degrees east and dip steeply to the north. They are traversed by a set of fracture planes striking north 40 degrees west, almost at right angles to the bedding planes, and many of the fractures are filled with quartz and other vein minerals. Another set of quartz veins is developed along the planes of bedding or schistosity; and, an increase in the amount of mineralization is often noticed where the two sets

[1] See also p. 251.

meet. The tungsten mineral wolframite occurs in many of the quartz veins though in others it is absent or was not observed.

The only vein of importance so far discovered is that on which the development work is being done. This vein strikes north 40 degrees west and dips 75 degrees to the southwest. It has been exposed for a distance of more than 150 feet, and at either end disappears under the drift. Its extension towards the northwest is indicated by a number of large pieces of float quartz carrying wolframite; 650 feet beyond in this direction a vein 12 inches wide outcrops and is perhaps the same vein. At its southeast end the vein passes under a deep covering of drift but its continuation is again indicated for at least 600 feet by many pieces of tungsten-bearing quartz along the strike. No rock in place was, however, found in this direction. The vein is faulted at the shaft and is displaced a few feet to the southwest.

At the collar of the shaft the vein is 24 inches wide increasing to 32 inches at a depth of 11 feet, and it maintains this width to the bottom of the shaft 50 feet below the surface. Along the strike it maintains a width of 2 feet northwestward for about 30 feet, beyond which for an interval of 20 feet it is difficult at present to determine the width. Sixty feet from the shaft the vein appears to be cut by a cross fracture which enriches the ore and increases its width to about 9 feet. Beyond this, it contracts again, except where cut by a second cross fracture, and, at a distance of 100 feet from the shaft, is only 12 inches wide.

The vein is a quartz-filled fissure on the walls of which replacement and mineralization have taken place to a depth of several inches. The gangue is quartz with a subordinate amount of topaz and some fluorite. The other minerals noted in the vein are wolframite, molybdenite, pyrrhotite, cassiterite, pyrite, arsenopyrite, and mica.

The wolframite occurs in large crystals both in the vein and the replaced wall rock. Its distribution is, however, somewhat irregular though it was observed throughout the greater part of the exposed portion of the vein. The ore in the exposed portion of the vein was estimated to carry from 2 to 6 per cent of wolframite or an average of $2\frac{1}{2}$ per cent WO_3.

The chief points in favour of the deposit are:

(1) The vein is a fissure vein which crosscuts the formation and thereby indicates some strength.

(2) The probable extension of the vein for several hundred feet in either direction beyond the 150 feet exposed, may be assumed from the presence of much tungsten-bearing quartz float and the outcrop of a 12-inch vein of similar character on the same strike 650 feet away.

(3) The vein is probably connected with the intrusion of the granite batholith, and its origin is due to uprising solutions emanating from the granite which is exposed about a mile away.

(4) The presence of other parallel tungsten-bearing veins in the vicinity, and of cross veins which tend to increase mineralization in the main veins.

The chief points against the deposit are:

(1) The presence of barren areas in the veins and the irregular distribution of the wolframite through the quartz.

(2) The liability of the vein to pinch, swell, or become split up into smaller veins.

The development work done on the vein consists of cutting down the hillside, stripping the vein for 150 feet, and the sinking of a shaft to a depth of 60 feet. A number of open-cuts had been made along the strike of the vein at either end of the exposed portion but none of them had got down to bedrock.

At the 50-foot level, drifts had been driven by October 17, for a distance of 24 feet in one direction and 31 feet in the other. At the face of the west

drift, the vein is 30 inches wide, while at the face of the east drift it is split up into four smaller veins with a few inches of country rock between. The total width of ore and included country rock is here 4 feet. On account of water in the sump below the 50-foot level, the vein was not seen at the bottom of the shaft.

On the 50-foot level the vein is of the same character and carries about the same percentage of wolframite as on the surface.

In the course of sinking the shaft and running the drifts about 250 tons of ore have been taken out and piled in a dump by the head frame. This with the 50 tons broken at the time of the examination in June makes a total of 300 tons in the ore pile.

The following summary will indicate the condition of the mine on October 17, 1916:

Ore broken and piled on the surface	300 tons of 2,000 lbs.
Ore proved by stripping, sinking, and drifting	1050 " " "
Total proved ore	1350 "

Estimating an average recovery of $2\frac{1}{2}$ per cent of WO_3 the quantity of 65 per cent concentrates recoverable $= \frac{1350 \times 2\frac{1}{2}}{65}$ tons $=$ 52 tons.

At the mine, the equipment consists of boiler, compressor, hoist and air drills, as well as blacksmith shop and head frame.

The mill which is situated on the bank of the Miramichi river about 2,000 feet east of the mine, was, on October 17, almost completed and ready to run. The machinery was all in place and the roof on, but the sides of the building were not completely sheeted.

The equipment of the mill consists of a 7 by 10 Blake crusher, one set of 10 by 30 rolls, a belt conveyor, Newaygo screen, two feeders, one 12 by 12 Richards pulsator jig, one Wilfley table, a 40-horsepower boiler, engine and pump.

At present the ore is brought from the mine to the mill in carts, but it is proposed to install some sort of haulage system operated by gravity, since the grade from the mine to the mill is about 6 per cent. No concentrates whatever had been produced up to October 17 but it was hoped that within a comparatively short time everything would be in running order. It is proposed to transport the concentrates by wagon to Maple Grove station 18 miles distant instead of using scows on the Miramichi river to Boiestown.

SCHEELITE MINE.

The Scheelite property is situated on Stillwater brook 2 miles west of Moose River Gold Mines in Halifax county, Nova Scotia. It is connected by a good wagon road, 18 miles in length, with the Canadian Government railway at Middle Musquodoboit.

The rocks of the mine are quartzites and slates in alternating beds and folded into a series of anticlines and synclines, which dip at angles from 15 to 90 degrees, and strike east and west. Compression has produced in the rocks well developed cleavage planes which dip nearly vertically and consequently cut the bedding planes at various angles. Considerable faulting occurs.

The veins containing the scheelite are similar to the gold-bearing veins in the adjoining gold mines. They follow the bedding planes and dip with the strata with a pitch of 5 to 15 degrees to the west. There are at least two or possibly three veins on the property, and they vary from 1 inch to 8 inches in thickness. The veins contain scheelite, quartz, mispickel, white mica, feldspar, a few needles of tourmaline, and much brownish calcite or ankerite. Where

mineralization has been greatest, impregnation of the wall rock by mispickel has taken place for a depth of several inches on either side. The scheelite is concentrated in the veins mainly at the apexes of the anticlines or in the troughs of synclines. It occurs in largest quantity in disconnected lenses 2 to 6 inches wide and from 6 inches to 2 feet or more in length. On the limbs of the folds where compression has been greatest, the veins are narrowest and are usually only about one inch wide. Here, they are often barren of scheelite for considerable distances.

From their mineral constituents the veins are believed to be of deep-seated origin and were formed under conditions of high temperature and pressure. Associated with them are large irregular veins of white quartz which are not mineralized and are apparently later than the scheelite veins.

The proportion of the scheelite in the veins was found to be very variable, but it was estimated that by carefully sorting out the rock a grade of ore could be obtained that would average about 10 per cent scheelite. In order, however, to obtain a ton of this ore, it would be necessary to break about 25 tons of rock.

The main vein has been traced by underground workings for a distance of 1,500 feet, but as yet it has been proved to carry scheelite for only 950 feet. On one limb of the anticline, it has been worked for several hundred feet from the outcrop, and on the other, for about 150 feet. The two other veins have been crosscut at a number of points, but very little ore has as yet been extracted from them.

It was found exceedingly difficult to make any estimate of the probable tonnage that could be obtained from the mine, both because of the lenticular character of the ore-bodies, and because of the irregular distribution of the scheelite throughout the veins. Taking, however, a length of 850 feet and a depth of 30 feet with an average width of 2 inches, there is a *possible* tonnage in the main vein of 425 tons of ore. This would yield 42·5 tons of concentrates, and since the concentrates have already been proved by mill-run to carry about 72 per cent of tungstic acid, this would mean about 30 tons of tungstic acid.

The other two veins may or may not contain as much scheelite, but together they might yield as much as the main vein, in which case the total possible tonnage of the mine would be about 85 tons of 72 per cent concentrates. This result, however, can be little more than a mere guess.

The ground in which the veins occur has been developed for a length of 1,500 feet, and a maximum width of 400 feet with a greatest depth of 190 feet. Water in the lower workings, however, prevented an examination being made below the 100-foot level. There are about 5,800 feet of underground workings consisting of shafts, winzes, drifts, crosscuts, and stopes. The main entry is an incline driven on the main vein. The mine had been closed down since 1913, but, in July, 1916, work was again started with a force of 12 men. Up to the end of September 40 tons of ore had been mined and raised to the surface, but none of this has yet been milled. It is the intention of the owners to keep this force at work in the mine until a considerable quantity of ore has been mined, and not to start the mill until a tonnage of ore has been accumulated sufficient to keep the mill running for some time.

The records of the Mines office in Halifax show the following number of tons milled and the concentrates recovered during the time the mill was in operation.

Year	*Tons milled*	*Concentrates recovered, tons*	*Per cent*
1912	340 (?)	15	4·4
1913	200	10	5·0

The mine is equipped with two boilers, compressor, hoisting machinery, pumps, ore cars and tracks, ore bins, and a number of houses.

The mill which was erected in 1911 contains a jaw crusher, rolls, two elevators, revolving screen, four slime tanks, four Wilfley tables, revolving roasting furnace, and magnetic separator. It has a capacity of 30 tons of ore in 24 hours, and appears to be in fairly good condition in spite of its having been closed for about three years. A description of the mill with flow sheet is given in the Nova Scotia Mines report for 1911, p. 209.

KAULBACK PROPERTY.

The Kaulback property is an old gold mine situated at the village of Moose River Gold Mines, Halifax county, and though now closed down had been worked for gold for many years.

At a depth of 150 feet from the surface in a crosscut from the main workings to the south, a narrow vein of quartz was encountered, which contains two lenses of scheelite. This vein is exposed in both walls of the crosscut in the form of a syncline with a buckle in the middle which forms a small anticline about 3 feet high. In the floor of the crosscut where the vein bends upward towards the central anticline, are two lenses of scheelite with mispickel, each about 6 inches wide and probably 2 to 3 feet long. This is all the scheelite that could be seen on the property at the time of examination in November, 1916, though float from the outcrop of the vein is stated to have been found at the surface. It is consequently difficult to form an opinion as to the value of the occurrence though scheelite may be expected to occur in the vein as it does at the Scheelite mine.

WAVERLEY DEPOSIT.

The Waverley deposit is situated in Halifax county $1\frac{1}{2}$ miles north of Waverley station, and east of Windsor Junction. It is an interbedded vein of quartz in quartzites, and carries some scheelite in places. The vein varies from 1 to 6 inches in width and has been traced for several hundred feet on the surface. A shaft was sunk some years ago, and several shallow pits made; but these were either full of water or caved in, so that it was impossible to make a satisfactory examination of the deposit. The occurrence is similar to those at Moose Mines.

INVESTIGATIONS IN NEW BRUNSWICK AND NOVA SCOTIA.

(*D. D. Cairnes.*)

Burnt Hill Tungsten Property,[1] N.B.

GENERAL STATEMENT.

The writer visited Burnt Hill Tungsten property (Figure 9) on November 25 for the purpose mainly of examining the mine and mill in order to determine what production might be expected in the near future.

Mining operations, since Mr. Camsell's visit, have been practically entirely directed to extending the drifts on the 50-foot level. A mill run of about 10 days had also been made, but the installation proved very inadequate, and the mill was closed on November 4, and has not since been in operation. About thirty-five men, in all, were employed in connexion with the development of the property, at the time of the writer's visit, two shifts being engaged in actual mining operations.

[1] See also p. 247.

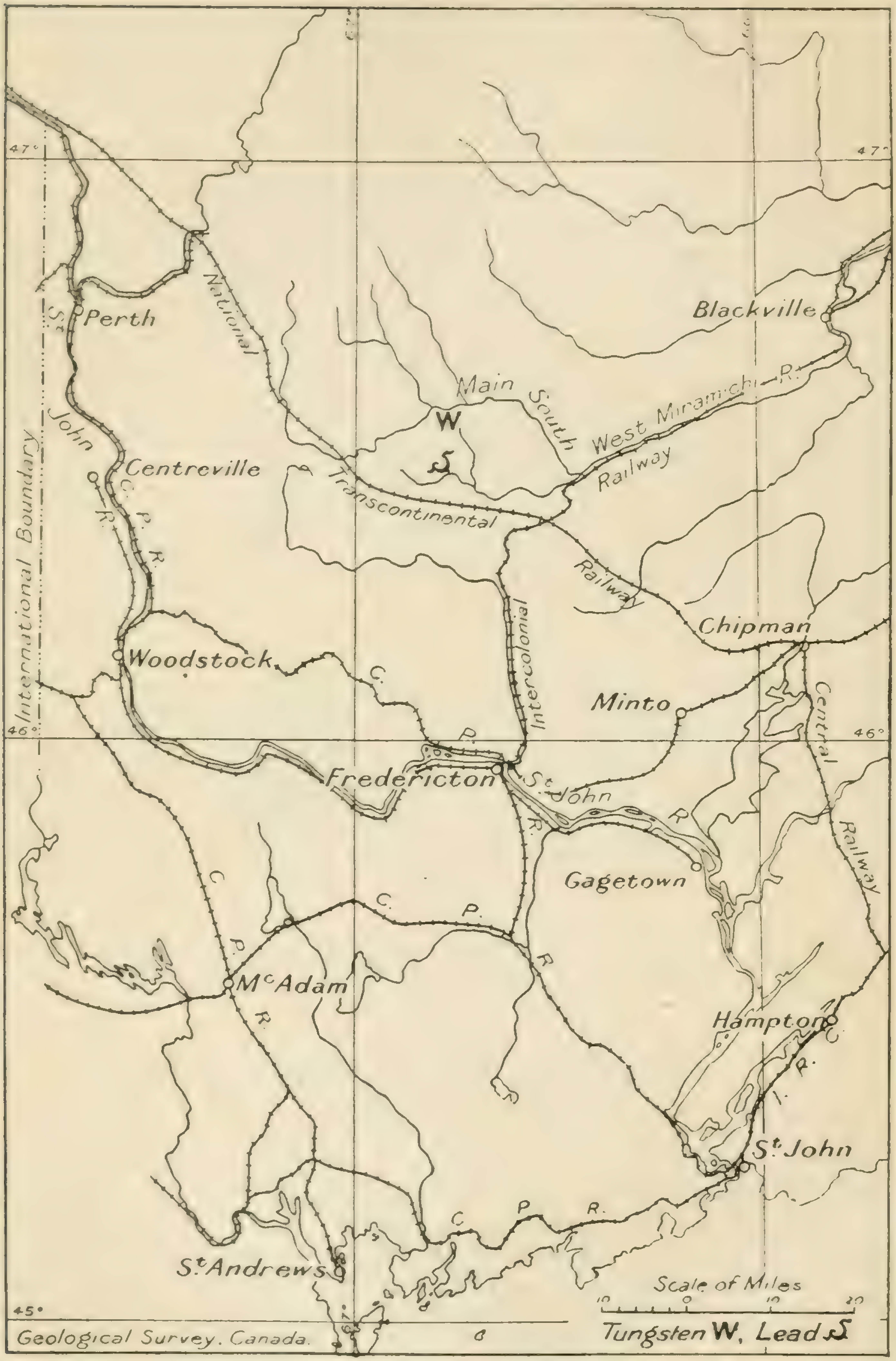


Figure 9. **Location** of tungsten and galena deposits, York county, N.B.

MINE.

Except for a certain amount of surface work of a prospecting nature, including a few open-cuts and shallow trenches, the development of the mine is restricted to a vertical shaft and drifts along the vein from the shaft in each direction. The shaft is 60 feet deep, and at the 50-foot level, a station was cut, and the drifts commenced. The bottom of the shaft is used as a sump. At the time of the writer's visit the drifts had been extended as follows: the drift to the northwest of the shaft, or the "west" drift as it is called, had been driven about 70 feet, and the drift to the southeast of the shaft or the "east" drift, had been driven about 65 feet. In the shaft, the quartz and other vein material range in thickness from 24 to 42 inches. In the west drift, the vein is in most places from 18 to 36 inches in thickness. Near the end of this drift, however, or about 70 feet from the shaft, the vein narrows to about one inch; but the last round of holes fired during the writer's visit, showed the vein to be there again, widening. In the east drift, there are in most places two veins, or really one main vein, and a narrower, parallel, stringer. These are generally 2 or 3 feet apart. About 50 or 55 feet from the shaft, the veins branch out into several stringers each about an inch or so thick, and finally the vein appears to feather out entirely; but before terminating, if it does so, the vein is cut off completely by a cross fault. The displacement or throw of this fault was not determined.

Considerable quartz float containing important amounts of wolframite is known to occur at various points along the hillside for a distance of several hundred feet to the southeast of the shaft, indicating that one or more wolframite-bearing veins occur there, one of which may be the same as that in the east drift. To the northwest of the shaft, also, outcrops of wolframite-bearing quartz veins from a few inches to 2 feet or even more in thickness, were seen at intervals, for a distance of about 1,000 feet. One line of outcrops appears to represent the vein in the shaft and drifts, but other outcrops containing important amounts of wolframite, definitely belong to one or more additional veins. It would appear very probable, however, from the surface outcrops, that the individual veins are not as persistent as had been hoped, but that, instead, the mineralization follows a set of more or less connected fissures lying somewhat *en échelon*. The present workings have blocked out about 1,500 tons of ore and on November 25, about 100 tons of ore was piled on the dump. Estimating an average recovery of $2\frac{1}{2}$ per cent WO_3, the quantity of 65 per cent concentrates recoverable from the 1,600 tons is 60 tons. It would seem now, however, that the recoverable WO_3 is nearer 2 than $2\frac{1}{2}$ per cent.

MILL.

The mill, at the time of the writer's visit, stood as it was when closed down on November 4. It had been roofed over but the walls were not completed. The equipment consisted mainly of a Blake crusher with a jaw measuring 8 inches by 16 inches; one set of 10 by 30 inch rolls; a belt conveyor; a Newaygo screen; a size 12 Richards pulsator jig; one Wilfley table; a 40-horsepower boiler; engine; and pump. The installation was found to be very inadequate for several reasons. The main trouble was that the rolls did not crush the ore nearly fine enough. The product after passing the rolls was very irregular, pieces $\frac{1}{4}$ to $\frac{1}{2}$ inch long or longer, being common. The wolframite and quartz thus still remained together in the individual particles, so that no separation by jig or table could be made. Experiments in the ore testing plant of the Department of Mines, Ottawa, have shown that the ore must be crushed to 16 or 20 mesh in order to give a good separation. In addition, considerable difficulty is reported to have been ex-

perienced with the Newaygo screen, except when the ore was quite dry, which was almost impossible to arrange economically.

As soon as the snow makes haulage practicable over the road from Maple Grove on the Transcontinental railway, it is proposed to freight in further equipment and lumber to remodel the mill and completely enclose it. Mr. H. M. Porteous, the resident superintendent in charge, expects to install a Hardinge ball mill, probably 4½ feet by 13 inches, to do the grinding after the Blake crusher. The ore is then to be fed to a trommel, and the products thence go to the Richards pulsator jig, a Kirby classifier, Wilfley table, and a Deister slimer. With some such equipment there should be no trouble in getting a satisfactory separation. It will probably be February, 1917, before the mill is again running.

Heretofore the ore has been conveyed to the mill from the mine, a distance of about 1,500 feet, by carts, but it is proposed either to install a system of gravity haulage, as there is a down grade from the mine to the mill of about 6 per cent, or to move the mill to a point nearer the mine.

During the ten days the mill was in operation, about 200 tons of ore was milled. From this, 23½ sacks of concentrates were obtained, which, it is estimated, weigh about 2,940 pounds. These concentrates represent three products, and a sample of each was taken. These samples were assayed by the Mines Branch of the Department of Mines, Ottawa.

Sample No. 1 is an average of about 1,625 pounds of a jig product. It was found to contain 61·80% WO_3.

Sample No. 2 is an average of about 690 pounds of hutch, also from the jig. It was found to contain 63·10% WO_3.

Sample No. 3 is an average of about 625 pounds of Wilfley concentrates. It was found to contain 48·65% WO_3.

Galena Prospect near Winding Hill, N.B.

The Winding Hill galena prospect is situated in Stanley parish, York county, New Brunswick. The mineral showings are close to the road leading from Taxes river to Miramichi river, and about 7 miles, measured along the road, in a northerly direction from Maple Grove station on the Transcontinental railway. A northerly branch of this road leads to the Burnt Hill tungsten mine and the road is at present mainly used for the transport of supplies to the mine. The galena prospect is held by five partners, William H. Griffin, William T. Griffin, G. N. Patriquin, D. C. Patriquin, and Stephen Logan, who have prospecting licenses covering thirty areas in this vicinity; these areas are 250 feet long by 150 feet wide, and apply only to gold and silver. In addition, the partners hold a search licence covering 5 square miles including the 30 areas and this licence applies to minerals other than gold and silver; but there is a provision in the Mining Act of New Brunswick by which the holders of these 5-mile search licences may mine silver under the ordinary terms of their leases, if the silver is associated with lead.

In the vicinity of the galena showing, the land is nearly everywhere timbered, and the bedrock is covered, in most places, by superficial deposits, so that prospecting is very difficult.

Development work on the property, when visited on November 25 (1916), consisted mainly of two trenches about 75 feet apart. One of these was 30 feet long, and 2 to 4 feet deep; the other was 12 feet long and 5 feet deep at the deepest point. About the only bedrock exposed in the immediate vicinity is that shown in these trenches. There the geological formation consists of greyish to light greyish green, interbanded quartzites and phyllites, which are much altered and metamorphosed, and are more or less schistose in most places. The

general strike of these old sediments is about north 5 degrees east, magnetic, and the trenches have been dug at about right angles to this direction, so as to crosscut the formation and the ore deposit.

The rock formation exposed in the trenches, especially the quartzitic bands, contains in places a considerable amount of quartz which occurs mainly in the form of irregular, ramifying veinlets and stringers, generally only a fraction of an inch in thickness. These are erratically distributed, but have a general trend parallel to the lamination of the containing rocks. The trenching on the property has exposed a zone in which quartz is extensively developed, with galena disseminated through it, as well as some pyrite. In the 30-foot trench, the mineralized zone, containing quartz and galena, is at least 18 feet wide. A sample, taken across 6 feet of the best mineralized portion of the exposed part of the zone, was assayed by the Mines Branch of the Department of Mines, Ottawa, and was found to contain no gold nor silver and 1·27 per cent lead. This lead at the December Toronto quotation of 9½ cents per pound, which is very high, amounts to $2.41 per ton. Another sample, taken across the best mineralized 8 feet in the 12-foot trench, was assayed by the Mines Branch, and was found to contain no gold nor silver, and 1·24 per cent lead, which at 9½ cents per pound amounts to $2.36 per ton. As these two trenches are not quite in alignment along the strike of the bedrock, they would indicate that the mineralized zone is at least 30 feet wide. The assays, however, indicate that the deposit so far explored, does not contain sufficient values to pay for mining. Further prospecting in this vicinity is, nevertheless, warranted, as, in a district exhibiting mineralization to this extent, profitable zones or veins are likely to occur.

Stirling Zinc-Copper-Lead Deposits, Cape Breton, N.S.

GENERAL STATEMENT.

The first work is believed to have been performed on the Stirling zinc-copper-lead deposits about twelve years ago. This work was of only a prospecting nature, and included the sinking of a shallow shaft or pit, and the digging of a few trenches or open-cuts. The only mineral that was known to occur in these deposits, which was considered to be of economic importance, was copper, and there did not appear to be enough of this to pay for working. Nothing further was done in the way of development until recently. Since the war the demand for various metals has greatly increased and one of those most required is zinc. Accordingly, as the Stirling deposits contain important amounts of this metal, the property was leased from the government of Nova Scotia on August 2, 1916, by James P. Nolan who obtained licences to search for minerals over five blocks of 5 square miles each. From these licensed tracts he selected and took up two leases each of one-half square mile, which include the right to prospect, mine, etc. One of these leases covers zinc and the other does not, in which latter case the zinc goes with the surface rights of the farmer who owns the land. An option on Nolan's leases was obtained by H. H. Sutherland of F. C. Sutherland and Company of Toronto, who also secured from the owner of the surface rights, an option on the zinc for the area of the lease not covering this metal. In addition, Mr. Sutherland obtained from the Nova Scotia government several permits to search for minerals in this vicinity.

During the past summer (1916) some surface development, mainly in the form of trenching, was done on the deposits, which showed them to be of decided economic importance. The writer was instructed by the Director of the Geological Survey to examine the occurrence, and accordingly a couple of days were spent in this district during the early part of December. The deposits were carefully examined and sampled, as far as exposed.

During the course of this examination, the writer was greatly assisted by Mr. John McLeod and Mr. John Madore, who bailed the water from the trenches, and helped in every way possible, to facilitate the work; to them, therefore, the writer wishes to express his sincere thanks and appreciation.

Since visiting this property, the writer is informed that it has been purchased by J. R. Ray and F. C. Sutherland and Company, both of Toronto, who have resold a 65 per cent interest to Hayden and Stone of New York, and the American Zinc Company of Boston. The new organization operating the property is named the Stirling Mining and Smelting Company. Diamond drilling was commenced and by the end of January (1917) was well under way, a 3,000-foot contract having been let. If the deposits prove satisfactory, extensive operations are contemplated for the immediate future.

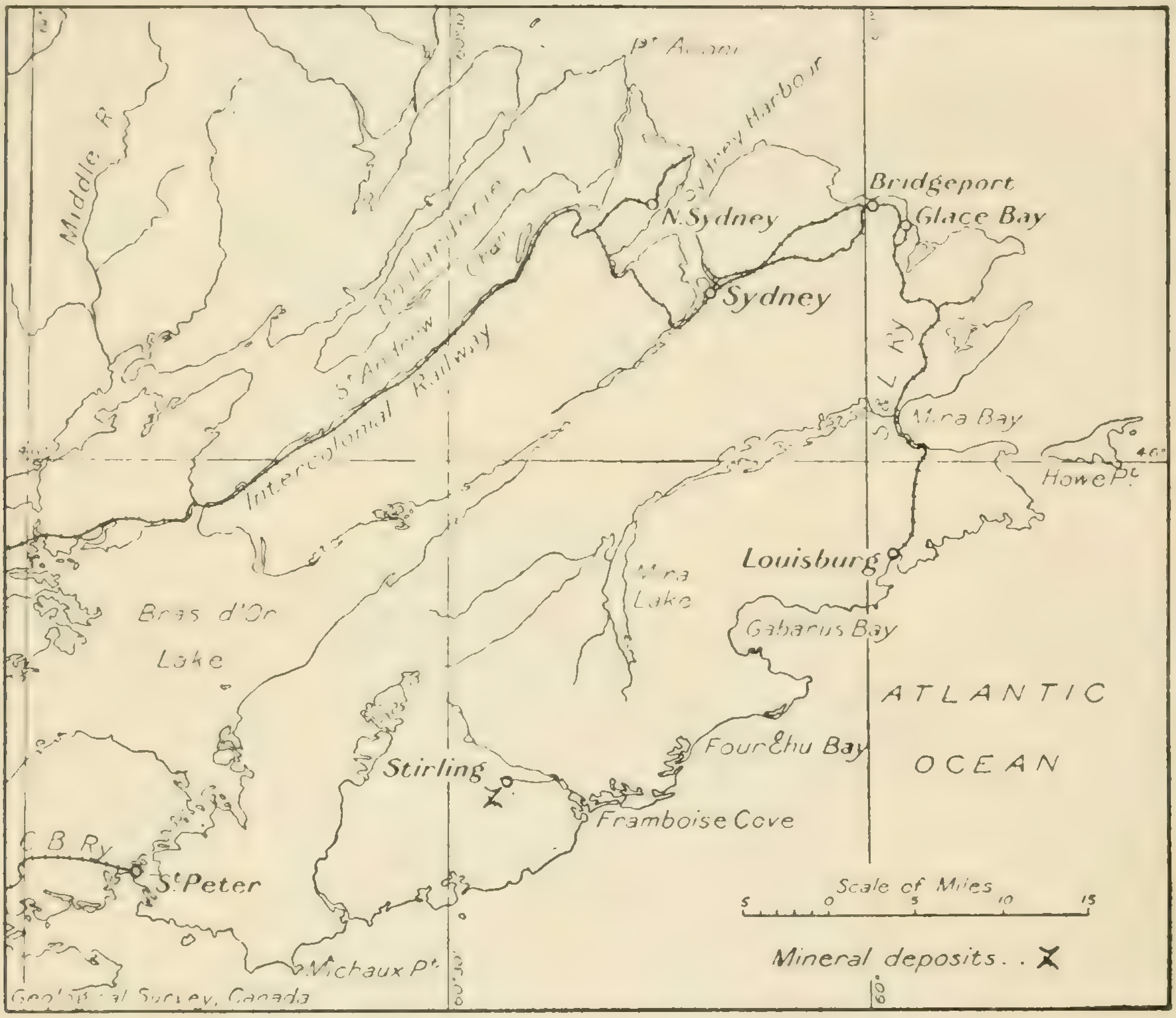


Figure 10. Location of Stirling zinc-copper-lead deposits.

LOCATION AND ACCESSIBILITY.

The Stirling zinc-copper-lead deposits are located in Richmond county, in the southwestern corner of Cape Breton island, N.S., and the development work is all within a few hundred yards of Stirling post-office which is part of the farm house of Mr. John McLeod. Stirling post-office is situated in a direct line between Loch Lomond and Framboise cove, and about 7 miles from Loch Lomond, and 5½ miles from Framboise cove, measured in an air line (Figure 10). The leases on which the Stirling deposits occur also adjoin the eastern end of Five Island lake.

To reach Stirling, it is customary to go via the Cape Breton railway which runs from Point Tupper to St. Peters. From St. Peters there are good roads to Stirling, a distance of between 35 and 40 miles. It is also possible to go by boat to Framboise cove or Fourchu bay, and thence drive to Stirling. Going in this way the best road at present runs from Fourchu bay, which is about 9 miles from Stirling, measured along the road.

Ore shipped from Stirling at the present time would have to go to tide water at Fourchu bay, but it is claimed that a shorter, more direct road could be constructed to Framboise cove.

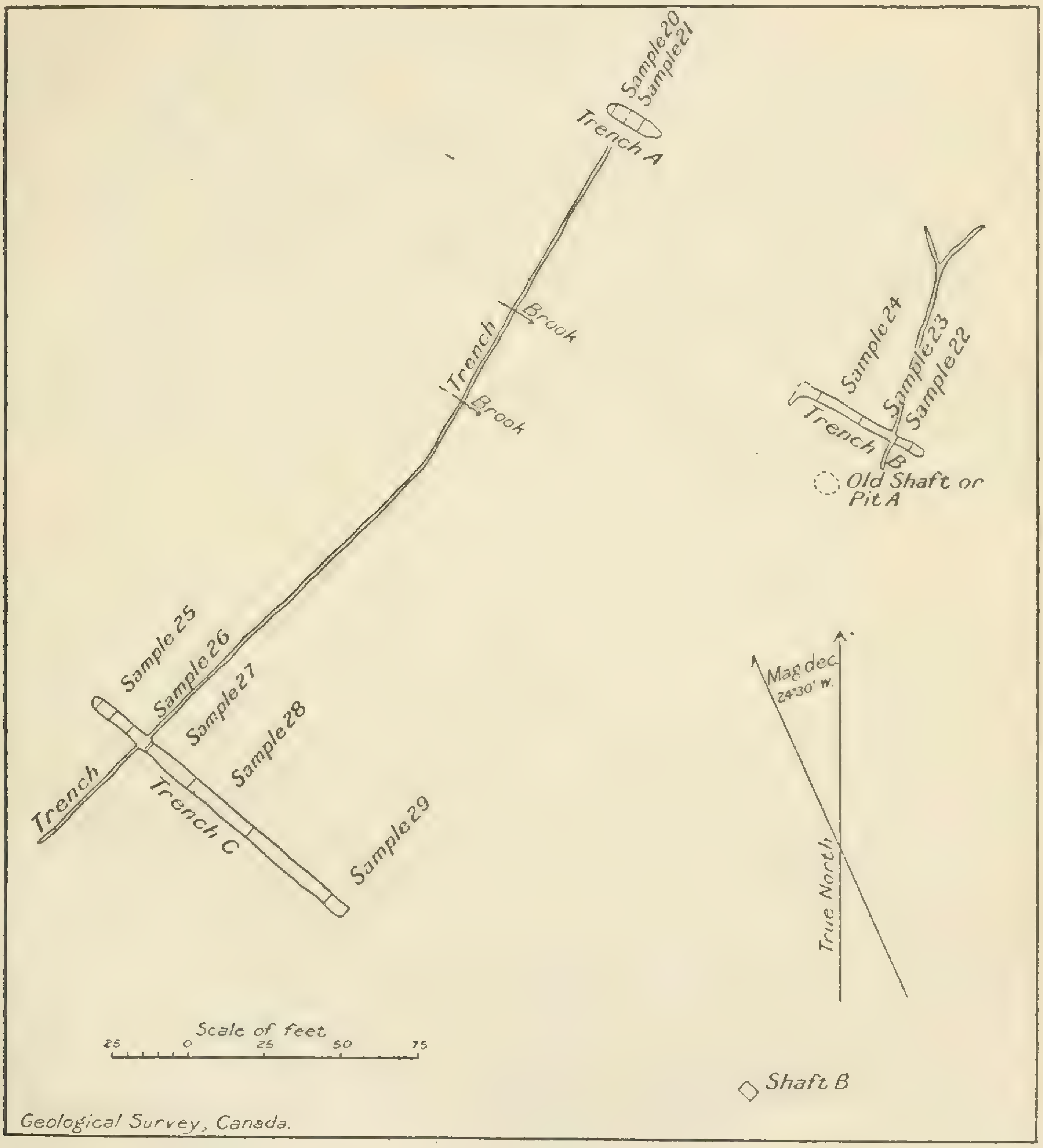


Figure 11. Plan of workings of Stirling property.

DEVELOPMENT.

The development work on this property is mainly in the form of trenching. One pit or shaft has been sunk to a depth of 14 feet, and another was sunk some years ago, but when visited had badly caved, and was full of water. Three main trenches have been dug across the ore deposits, which will here for convenience be designated as A, B, and C (Figure 11). No. A trench is about 20 feet long, 6

feet deep, and 4 or 5 feet wide; No. B trench is about 45 feet long, 2 to 4 feet deep, and 4 feet wide; and No. C trench is 108 feet long, 5 to 7 feet deep, and about 4 feet wide. These all run approximately at right angles to the general strike of the deposits. Also a small trench extends from A to C, a distance of 260 feet, crosses C, and persists possibly 50 feet farther. This trench is 1 to 2 feet wide, and 3 to 4 feet deep. Another small trench crosses trench B, and extends thence northward along the general strike of the deposit, about 60 feet. These trenches are all down to bedrock. Another trench about parallel to C, has been dug to the south of C, but did not reach bedrock, as the superficial deposits are there quite deep.

GENERAL DESCRIPTION OF AREA.

In the vicinity of these zinc-copper deposits, the land surface is dominantly flat and wet, and has been intensely glaciated. Glacial and other superficial deposits overlying the bedrock have a thickness in places of as much as 15 feet, but along the three main trenches are only a foot or so deep. The surface is also fairly heavily timbered, mainly with spruce, and numerous small streams traverse the area, but only very imperfectly drain it. Thus owing to the timber, soil, glacial, and other superficial deposits, very little bedrock is exposed in this vicinity, except in the trenches; but wherever the bedrock formation is exposed on either side of the ore deposits, it consists of massive, finely textured, dark greenish to greyish green, igneous rocks having the general appearance of andesites. Since, however, these rocks have not been examined microscopically, the general field name of greenstones is here applied to them. Possibly types related to andesites, including diorites, diabases, or basalts, may occur.

ORE DEPOSITS.

A shear zone having a general trend of apparently about north 65 degrees east (magnetic), traverses the greenstones, and it is within this zone that the ore deposits occur. Every transition may be noted from quite massive practically unaltered greenstones, to ore composed almost exclusively of zinc blende, chalcopyrite, pyrite, and quartz. The greenstones in places are merely sheared and altered to a greenstone schist. In other places pyrite has also been introduced in varying amounts. In places also, the rocks in addition to being sheared have been more or less entirely altered to a whitish, finely laminated, talcose substance. In other places, again, the original rock material has entirely given place to quartz, a whitish dolomitic mineral, zinc blende, chalcopyrite, and pyrite. Nearly everywhere, the ores are decidedly laminated, the lamination planes agreeing with the planes of shearing throughout the general shear zone. Even where solid ore now occurs, including mainly zinc blende and chalcopyrite, with some quartz, the lamination planes are still very decided. The deposits are thus evidently due, largely at least, to metasomatic replacement, and have been produced by uprising and circulating solutions, within the zone of shearing, which have more or less entirely replaced the original rock and have deposited along the planes of shearing the minerals now constituting the ore deposits. Sections were measured of the exposures in the bottoms of the three main trenches. These are shown in Figure 12.

All the ore material exposed in the bottoms of the three main crosscut trenches was sampled, ten samples being taken, which are numbered consecutively from 20 to 29 inclusive. Nos. 20 and 21 were taken from trench A; Nos. 22, 23, and 24 from trench B; and Nos. 25 to 29 inclusive from trench C. In trench A, 10 feet of ore is exposed, and in trench B, there is over 33 feet of ore material. The actual distance between the ends of these trenches is over 100 feet, and the

offset distance, measured at right angles to the supposed general direction of strike of the deposits, is about 90 feet, throughout which width it is not known whether ore occurs or not. Trench C is about 260 feet from A, measured along the general strike of the deposits, and ore material is exposed throughout this distance in the

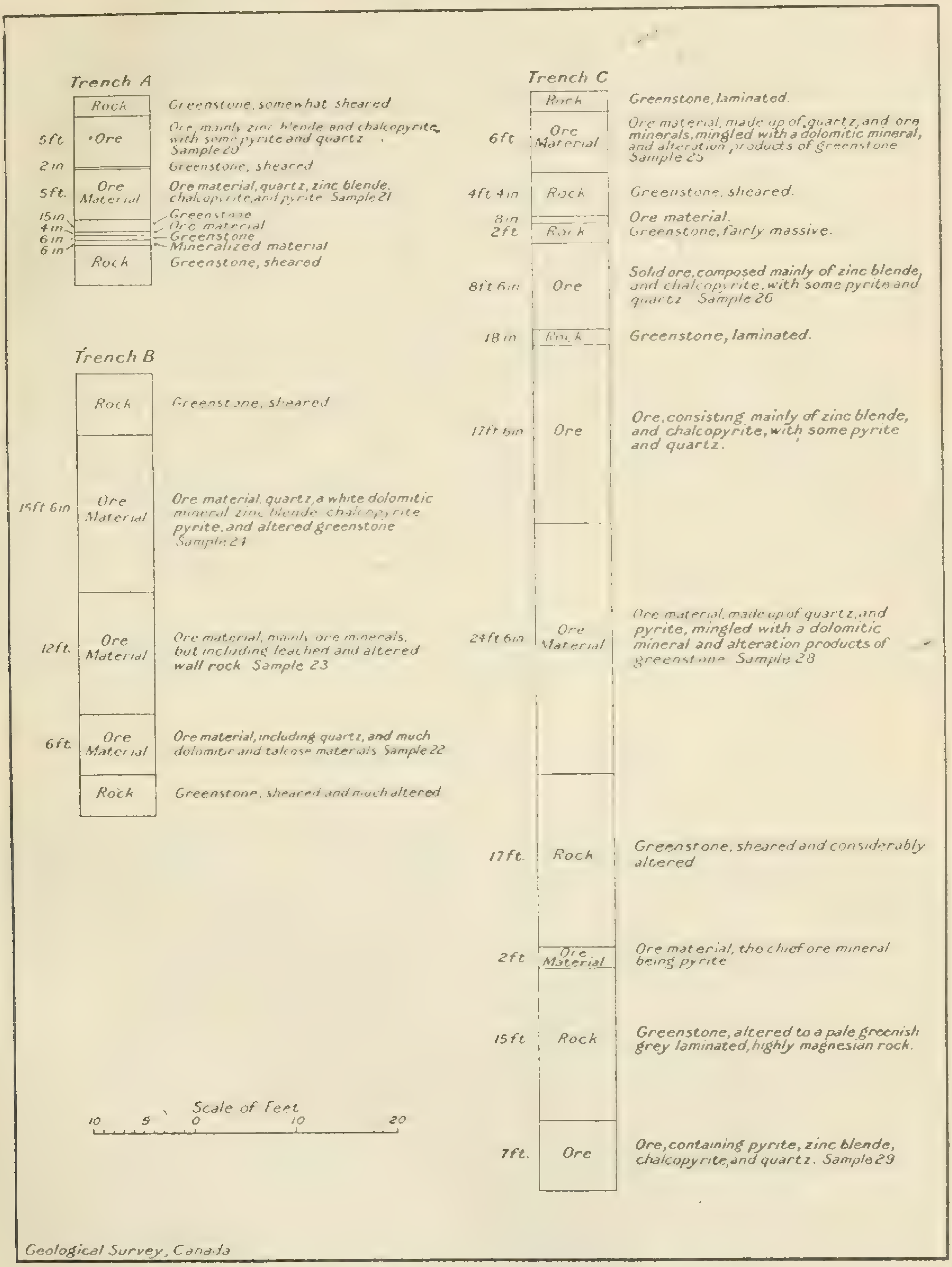


Figure 12. Sections across trenches, Stirling property.

bottom of a narrow trench extending from A to C. In trench C there is 66 feet of ore material, and about 135 feet still farther to the southeast, measured as an offset at right angles to the general strike of the deposits, a shaft has been sunk 14 feet in the bottom of which good ore was found (shaft B, Figure 11). No

work has yet been done to determine the amount of ore in this intervening 135 feet. Altogether these deposits have been actually traced by trenching along the general direction of strike, for a distance of over 300 feet, and they have an aggregate exposed width in trench C of over 66 feet. The amount of ore material here would thus seem to be decidedly important.

Figures 11 and 12 indicate where the samples were taken, and the latter also shows the character of material included in each sample. These were all assayed in the laboratory of the Mines Branch, Department of Mines, Ottawa, and the results are as follows:

Analyses of Stirling Ore.

No.	Percentages					Ounces, Troy, per ton 2,000 lbs.	
	Copper	Lead	Zinc	Antimony	Nickel	Gold	Silver
20	2·09	4·21	29·44	None	None	0·08	1·96
21	1·36	1·76	11·71	"	"	0·06	trace
22	0·52	1·40	3·71	"	"	0·06	"
23	0·23	0·11	3·88	"	"	0·04	0·25
24	0·67	2·34	7·90	"	"	0·04	trace
25	0·25	1·04	3·71	"	"	0·04	"
26	3·43	7·52	27·05	"	"	0·06	7·38
27	2·20	4·78	17·66	"	"	0·08	1·26
28	0·32	2·18	5·71	"	"	0·04	0·20
29	0·82	0·26	6·84	"	"	0·03	trace

SUMMARY AND CONCLUSION.

When visited, the Stirling deposits had been very slightly exposed, nowhere to a depth exceeding 7 feet. Thus no estimate of the ore in sight could be made that would do justice to the property. From what was seen, however, all the evidence indicated that the deposits are probably quite extensive, and persistent both longitudinally and vertically. The grade of much of the ore material is also high. In one trench, for a width of 10 feet, the ore carries from 11 to 30 per cent zinc, as well as significant amounts of lead, copper, gold, and silver. Also, in the main trench, there is 20 feet of ore containing 17 per cent to over 27 per cent zinc, as well as important amounts of lead and copper, and some gold and silver. In this trench, also, there is over 40 feet of ore material, which though of lower grade is still of consequence.

In the past, similar complicated zinc ores have presented many difficulties in the way of treatment, but a great amount of research and investigation has recently been done along these lines, and no doubt the owners of the Stirling deposits will be able to evolve a satisfactory method. In this event the deposits will become an important source of zinc-copper-lead ores in the near future. The finding and development of these deposits should also greatly stimulate prospecting in Cape Breton, and it is hoped that, as a result, other important ore-bodies will be found.

INVESTIGATIONS IN NEW BRUNSWICK AND NOVA SCOTIA.

(*A. O. Hayes.*)

GENERAL STATEMENT.

Field work was carried on in the Maritime Provinces as follows: In June two weeks were spent in a study of the Londonderry iron ore deposits in Colchester county, N.S.; and one week in an examination of a coal prospect at Maltempec, Gloucester county, N.B. In July and August geological mapping of a portion of Kings county, N.S., was carried on. This area is represented by sheet No. 103 and includes portions of the Nictaux-Torbrook iron ore district, the Annapolis valley, and North mountain to the bay of Fundy coast. In September two weeks were given to an examination of a recently discovered iron ore prospect at Piedmont, Pictou county, N.S., and to other iron ore localities in Pictou and Antigonish counties. Several localities on Cape Breton island were visited in the latter part of the month, including the George River dolomite and Point Edward limestone quarries and an occurrence of magnesite at Orangedale, Inverness county.

During the summer of 1915 a road material survey was made in the vicinity of St. John, N.B., and the results of this work are included in this report.

The writer wishes to acknowledge with gratitude the many courtesies received at each locality visited. The work of the Survey was facilitated by the kindness of Mr. J. P. Edwards, Londonderry, N.S., Messrs. J. B. Hachey and A. J. H. Stewart, Bathurst, N.B., Mr. F. H. C. Parsons, Middleton, N.S., Mr. A. R. Chambers, New Glasgow, N.S., Prof. E. Haycock, Wolfville, N.S., and others.

C. W. Robinson was appointed field assistant and J. F. Wright, student assistant; M. C. Foster assisted in telemeter surveying.

Londonderry Iron Ore Deposits, N.S.

Introduction.

The object of this report is to give any information obtained regarding the economic possibilities of these deposits. The mines were worked intermittently over the period from 1849 to 1908, but have been so long idle that the underground workings are now inaccessible. A study of surface conditions was made and descriptions of the character of the underground deposits received by consultation with former foremen in charge of the mines.

General Geology.

Various phases of the physiography and geology of the district, including the iron ore deposits, have been described by Sir Wm. Dawson,[1] Dr. A. R. C. Selwyn,[2] Prof. J. E. Woodman,[3] Henry Louis,[4] Hugh Fletcher,[5] and others. Woodman has given a detailed description of the mines with all available mine maps and plans and the reader is referred to his report for this information.

On the southern slope of the Cobequid hills the eroded edges of three series of sedimentary rocks, including pre-Carboniferous, Lower Carboniferous, and Triassic, are exposed in elongated areas striking east and west parallel to the north shore of Minas basin. The Triassic sediments lie unconformably above

[1] Dawson, Sir, J. W., Quart. Jour., Geol. Soc., 1850, p. 354.
[2] Selwyn, A. R. C., Geol. Surv., Can., Rept. of Prog., 1872–73, pp. 19–30.
[3] Woodman, J. E., Dept. of Mines, Mines Branch, "Report of the iron ore deposits of Nova Scotia", 1909, pp. 149–170.
[4] Louis, H. Trans. Nova Scotia Inst., Sc., 1879, pp. 47–51.
[5] Fletcher, H., Geol. Surv., Can., Ann. Rept., vol. V, pt. 2, 1890–91.

the Carboniferous which in turn overlap unconformably the pre-Carboniferous quartzites and slates in which the iron ore occurs. Plutonic intrusives form the higher portions of the Cobequid hills. These are intrusive into the oldest sediments and with these sediments the iron ore is associated. The intrusives are obviously older than Lower Carboniferous as pebbles derived from them occur in the Lower Carboniferous conglomerates lying at the foot of the hills on which the plutonic rocks are exposed. Only the rocks older than Carboniferous to which the iron ores are wholly confined, will receive further consideration.

The mineralized zone appears to have had its origin in the deposition of the carbonates of iron along a fault fissure in the sedimentary rocks, along the southern slope of the Cobequid hills, and paralleling their contact with the plutonic intrusives. These sediments, composed of fine-grained conglomerate, quartzites, and clay slates with occasional limestone and dolomite beds, are folded, crumpled, and broken in a complicated manner. The exact age of the series has not been definitely determined. Dawson[1] referred it to the Silurian, but in order to understand his conclusion it is necessary to review his data and classification. He published a geological map of Nova Scotia and divided the rocks into four groups as follows:

Granitic metamorphic
Syenitic metamorphic
Carboniferous
New Red sandstone

The Granitic metamorphic included the rocks limited to the Atlantic coast and its vicinity and comprised the slate and quartzites of the gold-bearing series, together with the associated plutonics. The Syenitic metamorphic referred to the metamorphic promontory extending from cape St. George and including the Antigonish, Merigomish, and Cobequid hills. He writes on their correlation as follows: "On their western side near Arisaig there is a patch of shale, slate, and thin-bedded limestone with Silurian fossils......the connexion of this group with strata containing upper Silurian fossils renders it probable that a great part of its beds belong to the Silurian system." The correlation is obviously on very general lines.

Fletcher[2] has mapped this series as Devonian and writes of his correlation as follows: "The iron ore of the Londonderry mines appears to occur in rocks identical with the reddish, green, and rusty slates which in Antigonish, Guysborough, and Pictou counties contain such a large quantity of specular iron ore which is worked at several places, a horizon intermediate between the two groups." (He subdivided the Devonian into three groups.) "It will be best perhaps to include them with the upper group as the red strata are characteristic. Like the Cambro-Silurian and Silurian these rocks, generally situated in the mountains, are so contorted that their relations to one another are not always easy to make out." Fletcher was evidently very much in doubt regarding the place of these rocks and in his last statement remarks on their similarity to the sediments older then Devonian. The writer was impressed with their resemblance both lithologically and structurally to the lower Ordovician of Pictou and Antigonish counties. Further detail stratigraphical work will have to be done before their age is more accurately determined.

Distribution of Mine Workings.

The mine workings extend intermittently along an east-west mineralized zone for a distance of about 10·5 miles. The largest ore-bodies were found at the western end between Cumberland brook and Martin brook, where under-

[1] Quart. Jour., Geol. Soc., 1850, p. 349.
[2] Geol. Surv., Can., Ann. Rept., vol. V, pt. 2, p. 17P.

ground levels were run in ore continuously for over 4,400 feet at depths of from 100 to over 400 feet below the surface. Little mining was done for a distance of over one mile between Martin and Cook brooks, but extensive ore-bodies were found at Cook brook and at the Acadia mines in what is known as the Old Mountain workings, on the east side of the west branch of Great Village river. The distance from Cumberland brook to Great Village river is about 2·5 miles and at the latter point between the west and east branches of the river furnaces are located at the village of Londonderry. Eastward from Londonderry, as far as Folly river, a distance of 4 miles, no ore-bodies of workable size have been found. East of Folly river at East Mines ore has been removed from deposits similar to those west of Londonderry. Farther east at Pine brook and Totten brook scattered small workings occur.

Mineralogy of Vein.

The minerals of the vein were studied by Sir Wm. Dawson and described as early as 1849, and republished in his Acadian Geology, 1878, pages 583-591. Henry Louis[1] also published a valuable paper on this subject, and a short summary of his results follows. He found that ankerite, sideroplesite, barite, calcite, aragonite, iron pyrites, and specular ore occur as original mineral constituents in the veins. Ankerite and sideroplesite occur together and are apparently contemporaneous in origin. Barite occurs in fissures in the ankerite. Calcite occurs as dogtooth spar and scalenohedra, lining fissures. Aragonite occurs in acicular crystals, and appears to be one of the last minerals to form. Iron pyrites occurs sparingly and specular ore is in thin veins ramifying through the ankerite. Red and brown ores occur as decomposition products of the carbonates of iron.

Analyses of the principal constituents are as follows:

Analyses of Minerals from Londonderry Iron Ore Deposits.

	Ankerite	Sideroplesite	Calcite
Insoluble siliceous matter	0·57	0·43	trace
Calcium carbonate	53·64	1·03	95·93
Ferrous carbonate	23·29	67·96	1·45
Manganous carbonate	0·77	2·19	2·77
Magnesium carbonate	21·48	27·87	0·57
Total	99·75	99·48	100·72
Specific gravity	2·988	3·523	——

[1] Trans. Nova Scotia Inst. Sc., 1879, p. 49.

Analyses of Ore from Londonderry Iron Ore Deposits.

	A	B
Insoluble matter	2·71	3·73
Alumina	trace	trace
Ferric oxide	87·21	83·21
Trimanganic tetroxide	1·67	1·83
Lime	trace	trace
Magnesia	0·45	0·65
Combined water	8·01	10·18
Phosphoric acid	trace	trace
Total	100·05	99·60

Analysis A was made on a deep red specimen and B on a brown specimen of the ore, both showing distinctly the cleavage planes of the original mineral.

General Structure of the Vein.

The vein has a general east-west strike and dips steeply to the south. The dip varies and at some points flattens to about 45 degrees. The associated sediments are altered, light green, soft, clay slate and quartzite. These have also a general steep dip southward and it is only at certain points that the fissure is seen definitely cutting across these beds. There is, however, no doubt that the vein does cut the sediments and that it is not an interbedded sediment altered to its present character, as suggested by Dawson.[1]

The ankerite, sideroplesite, and associated secondary oxides of iron, are, in general, restricted to a variable width of less than 100 feet, but, at certain localities pockety deposits occur scattered over a wider area. Thus a well-defined fissure vein extends for about 2 miles eastward from Cumberland to Martin brook and is broken up at the eastern end by cross faults in the Old Mountain workings. These scattered fissure veins extend over an area of 1,000 feet north and south, by 1,800 feet east and west. Similarly at East Mines the western portion of the deposit follows a straight fissure at the Slack Brook workings and is broken up at the east end as shown by the pockety condition of the Weatherbe Brook area. In both instances the broken areas lie closer to outliers of the plutonic intrusive. The fault zone may have been developed in the first instance during the period of diastrophism accompanying the intrusion of the igneous rocks.

Detailed Description of the Ore-Bodies.

The underground workings of the mines are inaccessible and the writer was fortunate enough to secure descriptions by Messrs. Mel. Spencer, M. Morash, and Farnem, foremen formerly in charge of the mines west of Londonderry and familiar with the development of the mines. They accompanied the writer to the surface workings and described the deposits. In the following description references will be given for quotations not verified by the writer.

Brooking Mine. The plutonic rocks intrusive into the iron-bearing sediments outcrop at distances varying from one-quarter to three-quarters of a mile north of the vein. North of the Old Mountain workings the contact of the intrusive with the sediments follows along the north side of the valley of an easterly flowing creek which empties into the east branch of Great Village river below the falls. About three-quarters of a mile up the creek a deposit of iron

[1] Acadian Geology, 1878, p. 588.

oxide occurs as a replacement of slate. This is known as the Brooking mine and the ore is called "Derry hematite." An average of eight analyses given in Woodman's report gives;

Metallic iron	38·71
Insoluble material	29·38

A section measured in an open-cut from south to north across the strike of the mineralized sediments is as follows:

Section at Brooking Mine.

Character of rock	Thickness	
	Feet	Inches
Coarse-grained sandstone	1	8
Fine-grained sandstone	3	2
Siliceous hematite (Derry)	6	0
Sandy clay slate	0	6
Purple slate	6	0
Brecciated slate	11	0
Purple rusty clay slate	17	0
Brecciated slate with chlorite	23	0
Sandy slate, covered to north	2	0
Calcareous sandstone with specular iron in veins, scattered outcrops through 15 feet. Covered to north, but steep slope suggests igneous contact about 50 feet north of preceding sandy slate.		

The igneous rock is exposed about 200 yards farther east and a thin section examined under the microscope shows it to be a coarse-grained diorite, composed essentially of plagioclase feldspar, augite, hornblende, and biotite, with unusually abundant black iron oxide. It seems probable that the hematite of the Brooking mine owes its origin to this plutonic intrusive.

About 5 miles east of this point at Pine brook the plutonic intrusive is composed entirely of plagioclase with some orthoclase feldspar. No ferromagnesian minerals nor iron oxide are present. A good section is exposed across the sediments below the contact, but no ferruginous deposits were found. The mineralization of the ankerite vein is also poorly developed at this locality and westward. These facts suggest the probability of a genetic relationship existing between the iron rich plutonics and the iron ore veins where structural conditions are favourable.

West Mines. In the workings west of Cumberland brook Mr. Morash stated that "ore was left in the lowest level (No. 2 north)". This is at the level of the brook about 478 feet above sea-level. "Ankerite occurs on a hard footwall and brown ore is associated with a soft hanging-wall; together these form a variable thickness of 10 to 20 feet. The good ore itself was 6 to 8 feet thick with a dip of 40 to 45 degrees to the south."

To recover the ore Mr. Morash suggested "driving a level to the south of No. 1 south level." Woodman states (page 155) that the ore west of Cumberland brook consists of a mixture of ankerite and siderite, and specular ore.

Cumberland Brook to Martin Brook. The surface cuts show the irregularity in the width of the vein. Between Cumberland brook and Dufferin shaft these vary in width up to 90 feet and average about 40 feet. Between Dufferin and McClellan shafts the outcrop narrows to 4 feet and averages 15. The walls are slickensided, indicating movement along the vein. About 600 feet east of McClellan shaft two parallel veins occur following the same fault zone and at 1,000 feet

east, at the water winze, two other veins lie at an angle to the main fissure bearing to the northwestward. Mr. Farnem stated that "at the Dufferin shaft 13 feet of ore was left in the bottom levels, Nos. 8 and 9". No ankerite was found on either wall in the upper part of the workings and black ore occurs more abundantly at Nos. 8 and 9 levels than at the surface. This ore could be best recovered by driving a drainage tunnel from a lower point such as the falls on Cumberland brook, as the water from these lowest levels would otherwise have to be pumped out. Black ore (botryoidal limonite) is unusually abundant eastward towards Martin brook and is in general associated with the brown ore. The red ore occurs with ankerite and sideroplesite.

The deepest mining of the whole range is at the Jamme shaft west of Martin brook where a depth of 230 feet below the level of the brook or less than 200 feet above sea-level has been reached. Mr. Morash stated "there is 60 feet of brown ore from No. 7 level to the bottom of the shaft. There is a slip in the hanging-wall of the vein at No. 7 level in which black iron ore occurs. A little ankerite was found on the footwall. There is little water in No. 7 or the Jamme workings and this would have to be pumped to recover the ore."

Woodman states (page 158) that in these and the Cumberland workings not only does the ore become lean downward but the proportion of sulphur increases rapidly.

Cook Brook Workings. Ore containing iron pyrites was found on the dump. Mr. Borash stated that "sulphide ore came from No. 1 east level 300 to 400 feet in. Brown ore mixed with ankerite was left on the sill of No. 3 level. This could be obtained by connecting up with underlying levels Nos. 1 or 2 to drain. No. 4 level crosses the vein and continues westward in foot-wall to the north of the vein. Specular hematite 4 feet thick occurs where this level crossed the vein, and dips nearly vertical or steeply to the south. Crosscuts show ore to south or main level. The altered vein rock is about 50 feet thick and clean brown ore 5 feet thick.

To recover the ore Mr. Borash suggests "drifting along it, driving Nos. 1 and 2 levels in to drain, and stoping up to Nos. 3 and 4 levels."

The vein is not continuous between Cook brook and Old Mountain workings. Slickensided rock walls terminated the vein abruptly at the western end of the Old Mountain levels and it is probable that cross faults have dislocated the vein at this point, also that the original character of the fissure was wider and more shattered, due to the proximity of intrusive plutonic rocks.

Old Mountain Workings. The ore occurred in a number of separate pockets along fissures, and these were found over an area 1,000 feet north and south by 1,800 feet east and west. Mr. Spencer stated that "the best ore from this locality was mined from a pit at the shaft over No. 2 level. This was brown ore with ankerite through it and measured 92 feet horizontally. The dip is 45 degrees to the south. No. 3 level crosses this vein from the north into the hanging-wall and then returns to the ore which continues downward. To mine below No. 3 a tunnel should be driven from No. 6 level to drain Nos. 4, 3, and 2 in turn, and stopes raised. This is the best place in Old Mountain to obtain ore. No. 1 level took ore from an old quarry but did not cut any quantity elsewhere. About 150 yards north of Gallagher workings 3 to 4 feet of black ore was found."

There are in the Old Mountain two distinct zones of mineralization along fissures marked on the surface by the quarry to the south and the Gallagher workings to the north.

Londonderry to Folly River. In the Ferguson workings about one-half mile north of Londonderry village, paint (yellow hydroxide of iron) was found but not in large quantities.

Along the strike of the mineralized zone eastward little is known of the character of the vein except where it is exposed in a railway cutting about one-third of a mile along the railway above the overhead road bridge, where a curve to the north brings the railway parallel to Folly river. A crushed zone about 200 feet wide is exposed and a clean cut fault occurs in the central part, exhibiting vertical walls with perfectly slickensided surfaces. The fault strikes north 95 degrees east and dips 86 degrees south. Ankerite occurs in small veins up to one inch thick throughout the crushed zone and mineralization is greater for 10 feet south of the main fault, but is present only in sufficient quantity to indicate a continuation of the zone. The sediments on the north side of the disturbed zone strike north 55 degrees east, dip 75 degrees northwest on the south side, strike north 45 degrees east, and dip 80 degrees southeast. The fault cuts across the bedding of the sediments.

Slack Brook Workings. A series of open-cuts along the surface show that a width of 15 to 40 feet has been taken out along a line striking north 75 degrees east, and dipping 82 degrees south. In the hanging-wall of the largest cut 15 feet of ankerite mixed with green altered clay slate 1 to 6 inches thick, remains. The foot-wall consists of soft interbedded clay slate and harder quartzitic layers. A slickensided surface 100 feet long and 60 feet high characterizes the foot-wall and specular hematite associated with ankerite is developed along it. At the east end of this cut a horse of broken altered sediments mixed with ankerite and small amounts of specular hematite is undoubtedly a replacement of the more finely comminuted fault breccia. The character of the ore removed was not learned.

Gory Brook Workings. No surface cuts occur between the Slack Brook and Gory Brook workings which are situated about 350 feet to the east, but the Slack Brook level connected them underground. A series of open-cuts and crushes extends for about 1,800 feet eastward, from which yellow, brown, and black ores were obtained. Mr. Oliver Slack, a resident farmer who was formerly employed in this mine, states that "some ore was left in the bottom on account of a crush." There is much water to pump unless a long tunnel be driven to drain the mine.

Weatherbe Brook Workings. The surface cuts change in strike from easterly to southeasterly and a number of scattered pockets occur in a manner similar to the Old Mountain workings. Here again also the plutonic intrusives are much nearer the mineralized zone and may have widened the shattered zone and deflected it southward. Ankerite occurs in veins up to 30 feet thick, and specular hematite in veins up to 6 inches thick. Brown ore was taken from the surface and appears to have been replaced by the ankerite with depth.

At the northeasterly limit of the workings a shaft was sunk 85 feet below the surface and Mr. Slack stated that "8 to 10 feet of yellow and brown ores with 4 feet of black ore (botryoidal limonite) were found on the foot-wall. The ore to the east of the shaft was not all stoped. It was partly stoped out on the west side and ore was left on the sill. There is much water and this caused difficulty in mining." Woodman (pages 149 to 170) states that the ore pinched out to the west of this shaft.

Pine Hill Brook. A mineralized zone in altered clay slate is exposed in the bed of Pine brook north of a bridge on a private road about three-quarters of a mile north of east Folly Mountain road. A vein of ankerite, including 1 to 2 feet of parting rock, measures 6 feet thick. Old workings, including a short tunnel and some open-cuts, were found on the steep hillside along the strike of the vein eastwards. The most extensive workings are at the top of the hill at what is known as the Barn Hill lot. The vein is exposed here for a width of from 30 to 50 feet. A marsh to the north of the exposure does not admit of accurate measurements of the vein. The vein strikes about east-northeast and

dips steeply to the south. No workable quantity of the oxides occurs, the ankerite being in a fresh state. Specular hematite was scattered through the ankerite in stringers and isolated masses.

Totten Brook Workings. A prospect pit occurs on the east side of Totten brook three-quarters of a mile north of the highway at Berry Totten's farmhouse. It is in brown ore, but too little work has been done to indicate the size of the deposit. About half a mile farther up stream the Totten Meadow workings are found. An underground level is crushed in and an open-cut above exposes a fault which has brecciated the ankerite vein itself. A fault breccia about 25 feet thick is made up of fragments of sedimentary rocks and fragments of vein material measuring up to 18 inches arcoss and surrounded by finely comminuted fault breccia. One of the large fragments of ankerite showed varying stages of alteration from the original mineral to red ore nearest the centre and to brown ore in the outer part. It is evident that considerable movement took place at this point since the iron minerals were first deposited.

A section from north to south at the mouth of the tunnel is as follows:

Foot-wall in clay slate, strike east, dip 26 degrees south.
Ankerite..6 feet.
Specular hematite, red ore, and rock...........................3 "
Hanging-wall much broken and accompanied by ankerite.......9 "

A small amount of brown ore has been mined from this locality. While the vein is well mineralized no large bodies of ore were seen and underground prospecting would be required to search for a workable deposit.

Summary.

The iron ore deposits occur in a fissure vein traversing sediments of early Palæozoic, probably Ordovician age. The fissured zone was formed during the period of earth movements accompanying the intrusion of plutonic rocks in Devonian time.

The most important iron-bearing minerals are ankerite and sideroplesite thought to have been derived from the plutonic magma and deposited by solutions at a sufficient distance from the heated mass to allow them to cool and to be deposited in their present form as carbonates. The presence generally of angular fragments embedded in the vein material suggests that replacement of comminuted fault breccia took place and may have modified the composition of magmatic solutions and precipitates.

The fissure zone may be cut off by the igneous rocks or possibly it may lie parallel to the igneous rocks. As the veins approach the contact of the plutonic with the sediments, minerals capable of deposition at higher temperatures, such as sulphides and oxides, probably take the place of the carbonates.

The mineralized zone, formed as it was along a line of weakness in the earth's crust, suffered subsequent dislocations during periods of diastrophism probably beginning with the Carboniferous. Denudation gradually exposed the shattered veins and the carbonates of iron were oxidized to limonites, producing yellow, red, and brown ochres, both on the surface and in deeper deposits along fissures in the vein. Carbonated waters dissolved and transported some of the iron, redepositing it in the form of botryoidal limonite and possibly in other forms similar to bog ore. The workable ore consists of these secondary hydrated oxides of iron, considerable quantities of which still exist in the old workings.

On account of the pockety nature of the deposits satisfactory prospecting in the old workings can be done only by drifting underground. Both the quantity and quality of the ore may decrease with depth. Prospecting for similar deposits of iron carried on along the continuation of this or other similar fissures may result in further discoveries of workable deposits.

Coal Prospect at Maltempec, Gloucester County, N.B.

COAL.

A thin seam of mixed coal and shale outcrops about 100 yards east of the highway on the east bank of a stream which joins the Pokemouche river $1\frac{1}{4}$ miles to the south.

The surface outcrop had been opened up previously and was again well exposed on the day it was examined. The following section was measured:

Section at Maltempec.

Stratum No.	Description	Thickness Feet	Inches
10	Thin-bedded, clay slate, top eroded	1	0
9	Thin-bedded, clay slate, stained by iron oxide	0	6
8	Thin-bedded, grey, clay slate	2	7
7	Massive, grey slate	0	2
6	Clay with coal stringers and yellow brown stain of iron oxide	0	8
5	Thin-bedded, clay shale and coal	0	$2\frac{1}{2}$
4	Thin-bedded coal with shale and iron pyrite	0	$3\frac{1}{2}$
	Thin-bedded coal and shale	0	$4\frac{1}{2}$
3	Thin-bedded coal with shale and iron pyrite	0	$4\frac{1}{2}$
2	Massive, grey clay	0	$10\frac{1}{2}$
1	Thin-bedded, clay shale in bottom		

Representative samples were selected from the seam and these were analysed by E. Stansfield of the Department of Mines with results as follow:

Analyses of Coal from Maltempec.

Analysis No.	238		237	
Stratum No.	3		4	
Moisture condition of sample	As received	Dry	As received	Dry
Proximate analysis:				
Moisture	5·9	....	6·2	....
Ash	20·6	21·9	50·4	53·8
Volatile matter	33·2	35·3	20·9	22·3
Fixed carbon (by difference)	40·3	42·8	22·5	23·9
Ultimate analysis:				
Sulphur	6·1	6·5	4·4	4·7
Fuel ratio, fixed carbon to volatile matter	1·20	1·20	1·05	1·05
Coking properties	Forms a very poor coke.		Non-coking.	

It is evident that this coal is lacking in both quantity and quality for commercial purposes.

Mr. T. G. Loggie, Deputy Minister of the Department of Lands and Mines of New Brunswick, kindly sent me copies of records of three diamond drill borings put down at this locality in 1906. The following statements are recorded:

Bore-hole No. 1 "at a depth of 41 feet 6 inches drilled through 1½ inches of coal. Blue slate over and under the coal." Bore-hole No. 2 "at 5 feet 6 inches from surface drilled through 8 inches of good coal." Bore-hole No. 3 "at 395 feet drilled through 3 inches of black slate and coal. The last 9 feet of sandstone contained small veins of coal about one-eighth of an inch thick."

The coal occurs as a bed in the sedimentary rocks and has a dip of about 5 degrees northeast. The drill holes were well placed both to test the known coal seam at greater depths along the dip, and to prospect for other seams. The records show that prospects for coal in workable quantity are not encouraging at this point.

Returning from Maltempec to Bathurst a hasty examination of the coast at Caraquet and Grand Anse was made.

At Caraquet along the shore east of the wharf, cross-bedded grey sandstone holds plant remains and occasional coal layers, some of which attain a thickness of 6 inches. These seams are of no great extent and form small lens-shaped masses usually highly pyritiferous.

SHALE.

West of the federal government wharf at Caraquet a purple shale occurs in a bed about 15 feet thick. It outcrops for about 1,000 feet along the coast, is underlain by grey sandstone, and is overlain by a thin mantle of gravels. A similar bed of shale occurs farther west outcropping on the shore opposite the church. At Clifton also it is exposed for about one mile along the coast with a gentle dip eastward. Samples from the exposures at Caraquet were tested by Mr. Keele of the Department of Mines and the following report received:

"Lab. No. 580. Reddish brown, crumbling, hard, massive clay shale, immediately west of the government wharf at Caraquet. This shale bed is about 15 feet thick, and is visible for about 1,000 feet. It is overlain by a thin deposit of gravels. This shale when ground and mixed with water to the proper consistency has good plasticity, and excellent working qualities. It can be dried safely in artificial driers, up to a temperature of 150 degrees Fahrenheit, but may crack if forced in a higher atmosphere. The shrinkage on drying is about 6 per cent. When burned to cone 010, it has a good, hard, red body with an absorption of only 9 per cent. If burned to the softening point of cone 03, the body is vitrified, but the fire shrinkage is high, being about 5 per cent. This shale fuses at cone 3.

"Lab. No. 581. Reddish brown, crumbling, hard, clay shale near church at Caraquet. The outcrop of the deposit extends for about 300 feet along the shore of the bay, and lies westward of No. 580. This material is similar to sample No. 580, giving almost identical results in the tests in the raw and burned conditions.

"These shales are suitable for the manufacture of wire-cut, building brick, fireproofing or hollow ware and dry-pressed brick. They would probably work well for roofing tile, and stiff-mud floor tile. They could be made into rough face brick and flashed to various shades of colour. They are of considerable economic importance on account of their easily accessible location, and the superior quality of structural wares which they would produce. A cheap fuel supply could be brought in by water, and the finished goods shipped by the same means to western points. It is doubtful if paving brick could be made from these shales as their range of vitrification is too short."

Geological Mapping in Annapolis and Kings Counties, N.S.

The area surveyed is outlined by Nova Scotia geological sheet No. 103, and extends from the contact of the granitic rocks between Nictaux river and the boundary between Annapolis and Kings counties northward across the Annapolis valley and North mountain to the bay of Fundy coast between Victoria harbour and Port Lorne. A base map of this district was surveyed under the direction of the late Hugh Fletcher, some years ago, and the partially completed manuscript of the map, on a scale of 1 mile to 1 inch, was used in the field.

The predominating feature of the landscape is the highlands of North and South mountains, between which the broad valley of the Annapolis river has been entrenched. There is an intimate relationship between the surface features and the character of the underlying rocks.

The rock series represented are as follows:

Table of Formations.

Era	Period	Age	Description
Cenozoic	Modern		River silt, humus, peat.
	Pleistocene		Boulder clay, stratified clay, sand, gravel.
Mesozoic	Triassic		Volcanic flows and amygdaloidal trap. Sandstone and shale.
Palæozoic	Devonian		Plutonic intrusives and dyke rocks.
		Oriskany (May be earlier in part)	Slates, quartzites, and oolitic, ferruginous beds composed of hematite, iron silicates, and magnetite. (Nictaux-Torbrook iron ores.)

Devonian Sediments.

Along the northern slope of South mountain a series of slates and quartzites with interbedded iron ores occur. These have been synclinally folded, with some close crumpling, faulted, and sheared. The series is richly fossiliferous and has been correlated with the Oriskany stage of the Devonian period. A thickness of several hundred feet of unfossiliferous quartzites and slates is exposed along the Nictaux river at Nictaux falls and northward. These have a steep dip to the south apparently conformable with the Oriskanian series.

Plutonic Intrusives and Dyke Rocks.

Dykes and larger masses of gabbro and diorite have penetrated these sediments and become increasingly abundant to the south, where, about 5 miles southeast of the Annapolis river, the main body of the plutonic rocks which floor the greater part of the interior of the western portion of Nova Scotia, is found. Bordering the contact is a zone about 1 mile in width composed of about equal parts of granitic and broken twisted and metamorphosed sediments. Since portions of this granitic batholith are elsewhere overlain unconformably by Lower Carboniferous conglomerates, the intrusion is thought to have taken place in the Devonian period.

Triassic Sediments and Basaltic Flows.

Triassic sandstone and shale of a characteristic salmon-red colour succeed the Devonian sediments to the north, but their contact is concealed underneath a mantle of glacial drift and outwash deposits. Scattered outcrops are found along the bed of the Annapolis river and in the deep cut valleys on the south slope of North mountain, where they are seen to dip gently northwards and to be overlain, apparently conformably, by basaltic flows, which present a precipitous escarpment facing the Annapolis valley to the south. The basal flow is usually the thickest and most coarsely crystalline at some points resembling an intrusive. The summit of North mountain is comparatively flat and is floored by the truncated edges of a number of flows. The north slope of the mountain is usually a nearly true dip slope of the flow.

Along the North Mountain coast, each flow varies in thickness from 0 to 80 feet, and exhibits amygdaloidal structure in its upper and lower portions. The dip is at angles of 10 to 12 degrees northward. Six or more successive flows are exposed along the coast between Port George and Margaretville. Thin clay partings frequently separate the flows, but these appear to have resulted from decomposition in place of both the underlying and overlying trap. No residual soils indicating time gaps were recognized.

This rock forms one of the best types of road metal and large quantities already partly crushed occur on the beaches along the coast, notably at Morden, also as talus along the precipitous cliffs on the south side of the mountain where it is easily accessible from roads crossing the mountain especially along the "Vault" road.

Surficial Geology.

Mr. C. W. Robinson gave his undivided attention to a study of the superficial geology, and mapped the various types of deposits in detail. Special attention was given to the glacial and alluvial deposits of the Annapolis valley. Information concerning the later stages of the Glacial period was obtained, especially in regard to the movement of local glaciers from South mountain northward. These crossed North mountain and furnished large quantities of sand and gravel now found as stratified deposits along the coast. These deposits were probably laid down in the form of a submerged bar when the sea stood about 200 feet higher than at present. A similar submerged bar exists at the present time along this coast at Margaretville, formed in part at least by ocean erosion of the Pleistocene deposits.

Gas Bubbling Through Sea Water.

An unusual phenomenon was observed at a point 2 miles west of Margaretville. Here a pre-Glacial valley about 2 miles in width was eroded to below the present sea-level, and later was entirely filled by glacial outwash sands and gravels. Modern wave action has undercut these soft deposits and the eroded scarp rises to an elevation of 170 feet above the present sea-level. The lower 120 feet of this is entirely composed of fine-grained sand, beautifully stratified and cross bedded; the upper 50 feet contains layers of coarse boulders. The gently sloping tidal beach is strewn with these fallen boulders which, embedded in sand, are exposed seaward at low tide for several hundred yards. The tides rise and fall here through a vertical distance of about 30 feet. While coasting along the beach in a small boat, when the tide was nearly in, gas bubbles were seen to rise copiously, bubbling through the water in a zone about 10 feet wide and extending in a curving line for about 300 feet roughly parallel to the water's edge. The bottom along this line would be exposed at low tide, and as a stream

flowed through these sands as well as the drainage from the outgoing tidal water, many openings would exist in the porous sand for air to be occluded when they were exposed above water, at low tide. With the incoming tide the air so trapped would be expelled by the pressure of the overlying water. The time of commencement of the bubbling was not noticed as the action was going on energetically when the locality was approached. It continued for over an hour. A sample of the gas was collected and examined and the following report has been received from Mr. E. Stansfield, chemist, Mines Department.

"The analysis shows that the sample was not merely atmospheric air trapped at low tide. The sample contained a minute trace of inflammable gas, apparently hydrogen, although the quantity was too small to distinguish with certainty between this and the more probable gas methane."

Carbon dioxide	0·66
Hydrogen ?	0·02
Oxygen	18·88
Nitrogen (by difference)	80·44
	100·00

Nictaux-Torbrook Iron Ores, N.S.

The iron ores occur as bedded deposits forming two nearly parallel zones about 5,000 feet apart. The southern zone, locally called the South Mountain bed, has been traced and test pits sunk along its outcrop from the Annapolis-Kings County line about halfway between the Canaan and Messenger roads, for about 5 miles southwestward past Bloomington towards the Nictaux river. It has proved too lean for further development.

The northern zone extends from Black river about half a mile north of the Messenger road to the west side of Nictaux river. The ore has been obtained principally from the Leckie bed and a small quantity from the overlying shell bed. Other beds occur in this zone which have not produced any ore.

According to the annual reports of the Nova Scotia Department of Mines, a total of 348,639 tons of ore were produced between the years 1891 and 1913. The mines are now idle and filled with water so that no underground study of the deposits could be made. The history and detailed descriptions of the mines with mine plans were published by Dr. J. E. Woodman[1] in his report on the iron ore deposits of Nova Scotia. The geology and stratigraphy of the iron ore series was described by Prof. L. W. Bailey[2] and Mr. Hugh Fletcher.[3] A magnetometric survey of the western portion of the Torbrook iron ore deposits was made by Mr. Howells Frechette[4] in 1910.

Petrography and Chemistry of Southern Zone.

The South Mountain bed is a ferruginous quartzite composed of magnetite, green iron silicate, detrital quartz, and fine-grained argillaceous material. It is frequently oolitic and at the eastern exposures contains hematite. Examined in thin section the green iron silicate is seen to occur in the form of spherules and also interstitially as a cement. The magnetite occurs as small masses usually with crystalline outline and appears to be closely associated with the silicate, as an alteration product. The rocks examined were considerably metamorposed. Chemical analyses of samples taken from the various test pits along the bed are listed in Frechette's report on page 8. An average of these is as follows:

[1] Mines Branch, Dept. of Mines, Bull. No. 20, 1909, pp. 48–170.
[2] Geol. Surv., Can., Ann. Rept., vol. IX, 1896, pp. 91M–123M.
[3] Geol. Surv., Can., Ann. Rept., vol. XVI, 1904, pp. 302A–318A.
[4] Mines Branch, Dept. of Mines, Bull. No. 7, 1912.

Analyses of Ore from south Mountain Bed.

	Percentage	No. of analyses
Metallic iron	40·80	17
Insoluble matter	24·62	12
Alumina	4·56	5
Lime	2·94	5
Magnesia	0·52	5
Phosphorus	1·56	7
Sulphur	0·016	7

Petrography and Chemistry of Northern Zone.

Thin sections from the Shell bed show that the ore is composed of detrital quartz grains and calcareous fossil fragments with which occur spherules of green iron silicate, having concentric structure. Crystalline magnetite has developed entirely within these spherules partially replacing the amorphous silicate. A very small amount of hematite is present. The spherules composed of both silicate and magnetite are frequently entirely embedded in a carbonate matrix which is probably calcite.

The green iron silicate resembles chamosite which is a hydrated ferrous aluminous silicate. The bed has a variable thickness where not disturbed by folding, of from 4 to 6 feet. As the name implies it is richly fossiliferous.

The Leckie bed also has an oolitic structure, at some points well and at others poorly developed.

Frechette states on page 9 of his report that the ore of the Leckie bed is slightly magnetic. No thin sections of this bed have been examined. Its thickness varies at the Leckie mine from 4 to 9 feet, according to Woodman's report, Plate 24, page 104.

The following averages of chemical analyses are taken from Woodman's report, page 14.

Analyses of Ore from Northern Zone.

	Leckie	No. of analyses	Shell	No. of analyses
Fe	49·20	229	44·13	81
SiO_2	15·09	17	16·60	81
Al_2O_3	4·42	9	4·84	6
CaO	4·94	6	6·79	7
MgO	0·67	6	......	..
MnO_2	0·74	8	......	..
P	0·92	55	0·75	25
S	0·077	11	0·098	11

The total iron content of the beds appears to have been originally supplied principally in the form of the green iron silicate, while the sediments were in the process of formation in shallow water along a marine coast. The hematite may also have been an original constituent but the magnetite appears to be an alteration product. Since the beds are primary sediments they are subject to variations from point to point as the character of the sedimentation changed along the coast. There is also a probability that the horizon is continuous between

the Leckie mine and westward where a thick mantle of drift has prevented prospecting for a distance of about 1 mile.

Iron Prospect at Piedmont, Pictou County, N.S.

Introduction.

In the autumn of 1915 a bed of oolitic hematite and green iron silicate 7 feet thick was discovered in a small creek valley on the northern slope of the range of hills south of Piedmont and about 1 mile southwest of Piedmont station, by James H. Robertson. The discoverer, associated with Messrs. Duncan Mackenzie and A. R. Chambers, made a number of open-cuts, in September 1916, to expose the bed. The writer visited the prospect in June and secured some loose specimens. The rocks were covered with such a heavy mantle of boulder clay that no study of the occurrence could be made until September, when two weeks were given to a survey of the prospect and surrounding country.

General Geology.

The coastal plain, floored by Carboniferous sandstones and conglomerates, rises gradually from the coast of Northumberland strait southward for 3 to 5 miles to an elevation of 250 feet, where it terminates abruptly in the hills south of the Piedmont road, which form a narrow ridge rising about 1,000 feet above sea-level. The ferruginous bed outcrops at an elevation of about 600 feet above sea-level.

The rocks in the range of hills south of Piedmont were mapped by Hugh Fletcher as of Ordovician age, and as similar bedded iron ores occurring on Doctor brook, Antigonish county, N.S., and also on Bell island, Newfoundland, are of lower Ordovician age the Piedmont occurrence probably belongs to the same period and may represent a similar horizon. The correctness of this correlation is indicated by the discovery in the shales and sandstones underlying the hematite, of brachiopod which has been identified by Mr. L. D. Burling as *Lingulella bella* Walcott. This species has been identified and described[1] from Bell island, Newfoundland, where it is referred on the basis of associated fossils to the lowermost Ordovician or the uppermost Cambrian.

It also occurs in zone 1 of the Wabana iron ore,[2] on Bell island, Newfoundland, and this horizon has been correlated by Prof. Gilbert van Ingen[3] with the French-Welch[4] facies of the lower Ordovician period, more particularly the Arenig of Wales and the Armoricain grit of Brittany.

Sections exposed in stream valleys on both north and south slopes of the ridge show that the Ordovician sediments lie in a synclinal fold with axes in an approximately east-west direction. Igneous intrusives occur in a large dyke-like form and apparently compose the core of the hills. Other dykes and volcanic rocks outcrop on the summit and northern slope but the relationship of these was not worked out. On the north slope a thickness of several hundred feet of reddish brown coloured conglomerates occurs. These are overlain by fine-grained green slates and sheared sandstones in which the oolitic hematite occurs. The *lingulella* occurs in the sandstone underlying the hematite bed. On the south slope coarse sandstones of similar colour and of about equal thickness to the conglomerates are overlain by slates and sandstones of similar character to those

[1] Walcott, C. D., Mon. U.S. Geol. Surv., vol. LI, 1912, pp. 481-482, Pls. XIX and XXXVI.
[2] Hayes, A. O., Geol. Surv., Can., Mem. 78, 1915, p. 22.
[3] van Ingen, Gilbert, Correlation table of Cambrian and Ordovician systems about Conception and Trinity bays, Newfoundland. Private publication, Princeton, N.J., July 9, 1914.
[4] van Ingen, Gilbert, Cambrian and Ordovician faunas of southeastern Newfoundland (abstract). Geol. Soc Am. Bull., vol. 25, No. 1, p. 138, March 30, 1914.

outcropping on the north side of the hill. The coarser texture of the sediments on the north slope suggests that an approach is made in this direction to the Ordovician shore-line.

Detailed Description of the Ferruginous Horizon.

The accompanying sketch map illustrates the structure as shown from the open-cuts. The section of the hematite bed immediately west of the fault on the west bank of the stream is as follows:

	Feet
Boulder clay	3
Green dyke composed of plagioclase feldspar and secondary calcite (top eroded)	5
Oolitic hematite, green iron silicate bed	7
Interbedded fine-grained green slate and sheared sandstone, holding fossil *lingulella*	3

The strike at this point is east and the dip 37 degrees south. Westward between the two faults the sediments are crumpled in a sharp fold pitching steeply to the south. Continuous surface cuts show that the fold is continuous. Fifty feet westward the strata strike northeast and dip 59 degrees southeast, while at the faulted contact with the volcanic rock the sediments strike south and dip 48 degrees east. Drag is well developed in the sediments at both faults and shows that the east side has moved southwards relative to the west side. The amount of throw of the west fault is unknown. The east fault ends in the massive ferruginous bed and appears to form a break along a sharp crumple of the strata. The eastern limb is flexed sharply southwards, and a clean slickensided fault face shows that there was a definite throw of the east limb southward. The thickness of the ferruginous bed is reduced at the fault from 7 to about 3 feet and it is still thinner where exposed in a cutting upstream to the southeast. Westward also the full thickness is not again shown apparently because of surface erosion.

The dyke which forms the hanging-wall of the ferruginous bed is apparently conformable with the latter but a good section was not found to confirm this, and it is possible that the dyke may cut across the hematite. The dyke is shattered along the fault but the evidence is not conclusive as to whether this is due to movement along the fault or to surface erosion.

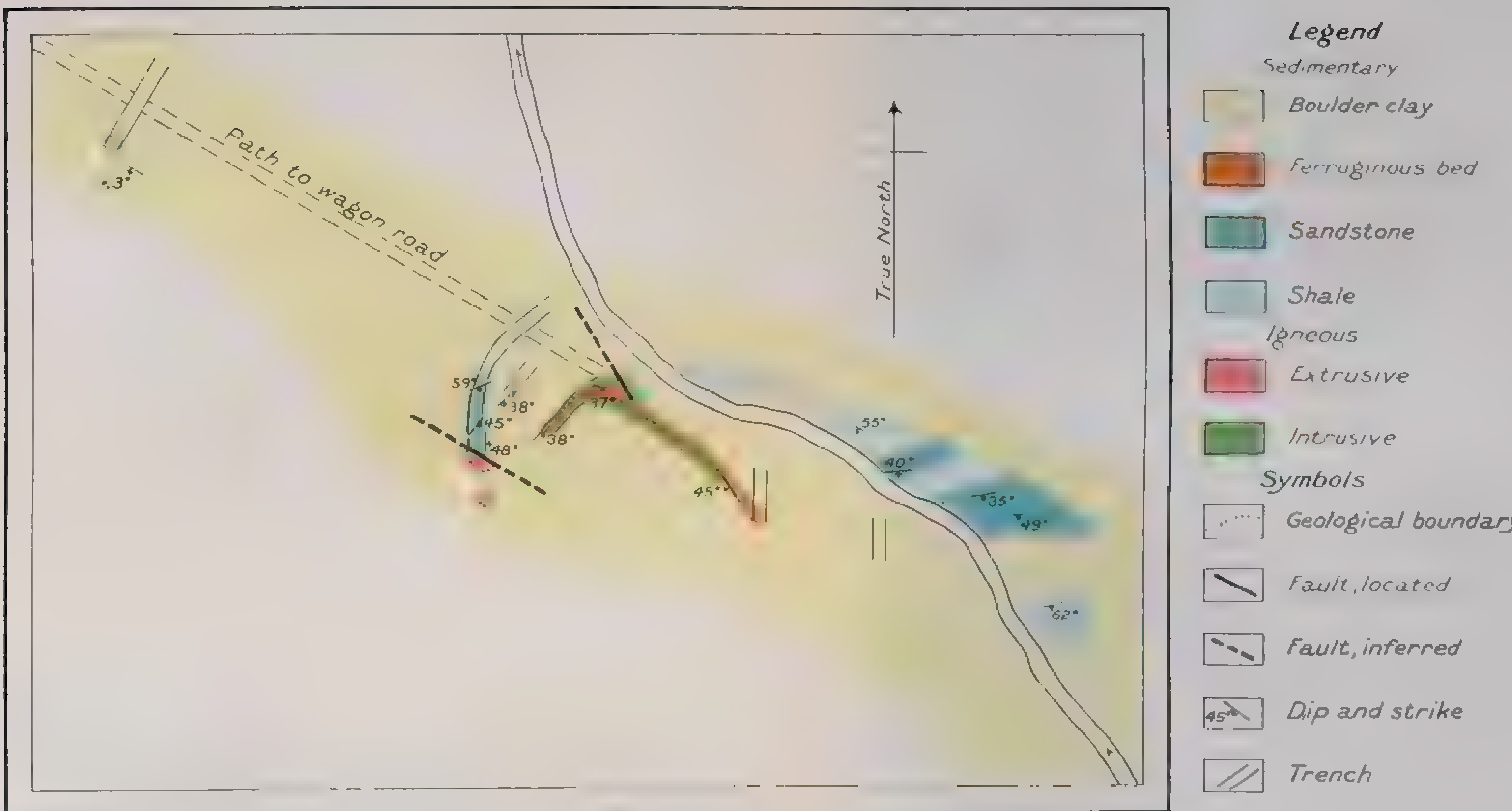
The sandstone and shale underlying the ferruginous bed to the southeast upstream along the east bank strike parallel with the stream for about 100 feet, when they again assume an east-west course and dip to the south. Slickensided and broken shales form about 15 feet of these strata and suggest that the movement which ended so abruptly in the ferruginous bed may have continued eastward in these less resistant beds and caused the throw southward to be greater than shown at the fault, and the thinning of the ferruginous bed to be due partly to stretching along the fold.

The hematite bed probably follows the trend of the sediments exposed and crosses the stream to the south. This point can be best determined by a continuation southward of surface strippings along the east bank of the stream where most of the superficial cover has been removed by stream erosion.

The volcanic rock to the west is not similar to the dyke overlying the ore, but appears from the small exposure to be an amygdaloid Its extent and relation to the sediments and the continuation of the ore westward of the fault is unknown.

Petrography of the Ferruginous Bed.

The ferruginous bed is composed of abundant detrital quartz grains in a matrix of a green iron silicate and hematite. These iron-bearing minerals occur



Geological Survey Canada

Catalogue No 1678

Iron ore bed, Piedmont, Pictou county, Nova Scotia.

Scale of Feet

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To accompany Summary Report by Albert O Hayes, 1916

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The ferruginous bed is composed of ... These iron-bearing minerals occur
matrix of a green iron silicate and hematite.

largely in the form of spherules usually built around a quartz grain as a nucleus. They also occur in masses with no definite structure. Small aggregates of shell fragments occur scattered irregularly through the rock. These are too small to identify but are probably from the fossil brachiopods of the genus *lingulella* similar to those found in the accompanying sediments. The *lingulellæ* are composed largely of calcium phosphate and, therefore, would supply phosphorus distributed irregularly throughout the bed. Hexagonal plates of hematite occur in the green iron silicate and represent various stages of crystal growth. It is probable that both silicate and oxide are of sedimentary origin but that the silicate formed first, and the hematite developed later by oxidation, in the unconsolidated sediments.

Three distinct beds of oolitic iron ore occur at Doctors brook, less than 20 miles to the northeast, in a geological horizon similar to that at Piedmont; likewise the Wabana iron ore of Newfoundland occurs in numerous beds through a thick series of sediments. It is, therefore, possible that other beds exist in this locality hidden underneath the drift. The bed at Piedmont is somewhat lean on account of the presence of detrital quartz together with a relatively high percentage of the silicates of iron. It is characteristic of these deposits to vary in character both along the strike and dip, for they are sedimentary deposits laid down in shallow offshore marine waters. The hematite and green iron silicate are each scattered in irregular masses throughout the bed and, consequently, the colour is a mottled dark green and reddish brown.

Partial chemical analyses of samples from the ferruginous bed and of the overlying dyke have been made and results follow:

Analyses of Piedmont Iron Ore.

	1	2	3	4
SiO_2	42·42	18·56	21·24	42·51
Fe total	16·30	46·46	42·00	6·02
P	2·84	0·76	0·704	0·21
TiO_2	......	......	1·58	......
CaO	......	......	......	6·46
Sulphur	......	......	0·034	......

1. Selected sample of green iron silicate.
2. Selected sample of hematite.
3. Average sample of ferruginous bed.
4. Dyke overlying ferruginous bed.

H. A. Leverin, chemist, Department of Mines laboratory.

While working in this district Mr. Robertson accompanied the writer to a mineralized zone on the mountain slope on the north side of Barney river about 2 miles west of Marshy Hope. Specular iron occurs there in a vein about 4 inches thick. A sample taken from the vein was assayed by H. A. Leverin and gave the following results:

Gold................................trace.
Silver................................none.

Magnesite at Orangedale, Inverness County, N.S.

A deposit of magnesite was discovered by Alexander McLeod on the farm of John Martin, McLean Point road, about one mile east of Orangedale. The writer visited this locality on October 6. An open-cut, about 5 feet wide by 15

feet east and west through about 3 feet of surface sand and clay, exposed the magnesite. It is in a weathered and friable condition over the whole extent of the stripping. The property has been acquired by the Nova Scotia Steel and Coal Company and a trial shipment of 30 tons taken out since the writer's visit.

The magnesite occurs in a crystalline form. At least two varieties of crystals occur; the most abundant is a six-sided prism of brown colour, and the other resembles a scalenohedron and is nearly colourless. Each varies in size up to about half an inch in length. Bedrock was not exposed in the cutting but small cores of dolomite occur in the magnesite and the six-sided prisms were found embedded in the cores. Fossiliferous dolomite interbedded with gypsum, probably forming part of the Windsor stage of the Carboniferous limestone series, is well exposed in a quarry about one-quarter of a mile south of the magnesite prospect. An analysis of this dolomite is given below.

Analyses of Magnesite and Associated Rocks from Orangedale.

	1	2	3
$CaCO_3$	2·85	53·00	92·07
$MgCO_3$	90·80	41·38	0·89
Al_2O_3	1·01	0·08	0·37
Oxide of iron all expressed as Fe_2O_3	1·71	0·80	0·57
Silica and insoluble residue	0·30	3·46	3·60
Equivalent to			
CaO	1·60	29·68	51·46
MgO	43·53	19·80	0·43

1. Weathered specimen crystalline magnesite.
2. Fossiliferous dolomite from quarry.
3. Limestone from shore of lake north of magnesite deposit.

Analyst, H. A. Leverin. Laboratory report No. 3383.

Other outcrops of the Carboniferous limestone series occur to the north of the deposit, one within a few hundred feet, the other on the shore of the lake. The deposit of magnesite is apparently of secondary origin derived from the associated dolomites.

Road Materials in the Vicinity of St. John, N.B.

INTRODUCTION.

Both bedrock and gravel suitable for road construction occur in the vicinity of St. John and are easily accessible for use in the city or on highways leading to the city. Transportation by water or rail is available. A survey of these materials was commenced in 1915 and samples were selected from the most important localities for special study. Seven samples of bedrock and twelve samples of gravel were tested in the laboratory of Columbia university under the direction of Prof. A. H. Blanchary, C.E. The results of these tests are given in the accompanying tables. Laboratory tests devised to approximate the conditions which obtain in a road bed under traffic furnish a means of determining the value of material for road construction.

The methods for the determination of the physical properties of road building rock are described with illustrations in Bulletin No. 347 of the United States

Department of Agriculture, by Frank H. Jackson, jun. Definitions of the physical properties are given in Bulletin 348, United States Department of Agriculture, by E. C. E. Lord, and also in Memoir 85, Canada, Department of Mines, Geological Survey, by L. Reinecke.

Per cent of wear represents the amount of material under 0·16 centimetre in diameter lost by abrasion from a quantity of rock fragments as nearly uniform in size as possible between 2 and $2\frac{1}{2}$ inches in diameter and weighing within 10 grams of 5 kilograms. About fifty fragments are placed in a closed cylinder and revolved five hours at the rate of 2,000 revolutions per hour. The abraded material is then screened through a $\frac{1}{16}$-inch-mesh sieve and from the amount lost the per cent of wear is determined. This loss may also be expressed by the French coefficient given below:

$$\textit{Coefficient of wear} = 20 \times \frac{20}{W} = \frac{400}{W} = \frac{40}{\textit{per cent of wear}}$$

where W is the weight in grams of the abraded material under 0·16 cm. (one-sixteenth inch) in diameter per kilogram of rock used.

Hardness is the resistance which a material offers to the displacement of its particles by friction and the test is made on a cylindrical rock core 25 millimetres in diameter. The test piece is held perpendicularly under a constant pressure of 1,250 grams, against a revolving cast steel disk, while standard quartz sand, between 30 and 40 mesh, is used as the abrasive agent. From the average loss in weight computed from two runs, the coefficient of hardness is obtained by deducting one-third of this loss, expressed in grams per 1,000 revolutions, from an arbitrary constant (20). The coefficient 20 was chosen as the standard of comparison to give about the same range of values as those obtained by the abrasion test. The loss in weight is divided by three in order to avoid negative coefficients.

Toughness as here understood, is the resistance a material offers to fracture by impact. The test piece is a cylindrical rock core 25 millimetres high by 25 millimetres in diameter, and the test is made with an impact machine constructed on the principle of a pile driver. The blow is delivered by a hammer weighing 2 kilograms, raised by a sprocket chain and released automatically by a concentric electro-magnet to fall on an armor-piercing steel plunger with spherical lower end which is in contact with the upper surface of the test piece. The test consists of a 1-centimetre fall of the hammer for the first blow and an increased fall of 1 centimetre for each successive blow until failure of the test piece occurs. The number of blows required to cause rupture represents the toughness.

The cementing value is the property possessed by a rock dust to cement or bind together the coarser rock fragments, and the test is carried out as follows: one-half kilogram of rock is broken sufficiently small to pass a half-inch-mesh screen and is then moistened with 90 cubic centimetres of water and placed in a cast-iron ball mill, containing two cast-steel shot, 5 inches in diameter and weighing about 20 pounds each. The sample is ground for $2\frac{1}{2}$ hours at the rate of 2,000 revolutions per hour or until the material has been reduced to a thick dough, the particles of which are not above 0·25 millimetre in diameter. The dough is then removed and moulded into cylindrical briquettes 25 millimetres in diameter and 25 millimetres high, in a hydraulic briquette-forming machine, so adjusted as to give a maximum momentary pressure of 132 kilos per square centimetre on the compressed material. Five briquettes are made from each test sample which, after being thoroughly dried at 200 degrees F. and cooled in a desiccator, are broken by an especially designed impact machine having a 1-kilogram pendulum hammer with an effective drop of 1 centimetre. The average

number of blows required to destroy the bond of cementation in five briquettes determines the cementing value of the rock sample.

Specific gravity is the weight of the material compared with that of an equal volume of water, and is obtained by dividing the weight in air of a rock fragment by the difference between its weight in air and water. The weight per cubic foot of rock is found by multiplying the specific gravity by 62·37 pounds, the weight of a cubic foot of water.

Absorption determines approximately the effect which frost will have upon a rock mass. Most rocks which are good for road metal have a very low absorption.

The following specifications were adopted by the American Society of Municipal Improvement in October 1914, as a result of comparisons made by engineers between laboratory tests and the wear of the stone in practice.

For a broken stone road without a bitumen binder the stone shall have a French coefficient of wear of not less than 7 (per cent wear of about 5·7) and its toughness shall not be less than 6.

For a broken stone road with bitumen binder the lower courses shall conform to the above specifications, but the stone in the top course shall have a French coefficient of wear of not less than 11 (per cent of wear of about 3·6) and a toughness of not less than 13·0.

BEDROCK.

No. 1. Rockland Road Quarry. This quarry is operated by St. John city for road material in city street construction. The rock is a fine-grained, massive trachytic volcanic much shattered by earth movements and altered along joint cracks. The present quarry floor is on a level with Rockland road and is at the top of a hill so that drainage is good.

This type of rock outcrops along the hill slope to the northeast between Seeley street and Mt. Pleasant avenue where it forms a ridge about 400 feet wide. It dips steeply to the south. This rock has been used in the construction of a number of streets in St. John city, apparently with satisfactory results. It does not cement as well as the diabase, and consequently may prove to wear more quickly, especially under heavy traffic.

No. 2. City Quarry West St. John. This quarry is in sedimentary rocks and a detailed section across the west face of the quarry from north to south in ascending order is as follows:

Section in City Quarry, West St. John.

No.	Description	Thickness Ft.	In.
1	Light to dark grey, fine-grained micaceous sandstone	12	6
2	Reddish, micaceous sandstone, shaly at top	5	6
3	Medium-grained, reddish grey sandstone	7	0
4	Reddish sandstone similar to No. 2	7	0
5	Grey, compact, fine-grained, micaceous sandstone, banding in upper 3 feet	23	6
6	Red shaly micaceous sandstone	3	0
7	Grey, fine-grained, micaceous sandstone	8	0
8	Fault nearly parallel to bedding with chloritic material	0	4
9	Grey sandstone	5	0
10	Reddish sandstone, laminated and easily cleaved	15	..
11	Grey, shaly sandstone	5	6
12	Coarse, grey sandstone	2	..
13	Reddish grey sandstone	1	6
14	Fault, strike 75 to 45 degrees north. Rocks slickensided	..	..
15	Red, shaly, micaceous sandstone	6	..
16	Grey somewhat shaly sandstone with reddish layers. Cleaves easily	5	6
17	Greenish grey sandstone	3	..
18	Sandy shale, reddish grey	7	..
	The rocks have a strike of north 55 degrees east and dip 77 degrees to the south.		

This sandstone and shale is easily quarried and is situated on fairly high ground. In wet weather the quarry floor is flooded, a face of 13 feet being exposed above water.

The percentage of wear of an average sample across the face is very high, i.e., 9·7. The toughness test was made on a selected specimen of sandstone and represents the most resistant material available. The average toughness is much lower. A comparison with the diabase which occurs in West St. John indicates that this material is much less efficient in every way for road construction.

The material falls below the standard for a broken stone road, and where used for the upper courses the road may prove to be dusty in dry weather, muddy in wet weather, and to have comparatively short life.

Massive and amygdaloidal diabase, which occurs in the form of dykes and sills and perhaps in part as volcanic flows, intrudes and accompanies the sediments at the base of the Little River series. These igneous rocks form a band varying in width from a few hundred to over 1,000 feet, and extend from the east shore of Courtenay bay southwestward. They are exposed at the corner of Britain and Pitt streets on St. John peninsula and again across the harbour in West St. John where they form the higher land and widen to between 1,000 and 2,000 feet. They are covered to the west of Duck cove by stratified sands and gravels. An isolated area of massive diabase extends from Sand cove to Sheldon point forming this precipitous shore which rises in a cliff over 80 feet in height for a distance of about three-quarters of a mile.

Five tests of this material have been made from samples taken from the most easily accessible localities for quarrying. Experience has shown that rock of this type makes excellent road material.

No. 3. St. John County Quarry. This diabase outcrops from the Courtenay Bay shore north of the breakwater and forms the small hill rising 140 feet above sea-level, east of the reformatory. It is amygdaloidal in the southern part and

is somewhat broken by joint cracks. The more massive rock was quarried from the western portion of the area for the construction of the breakwater. From the north side the rock was quarried for the construction of the Loch Lomond road from Kane corner eastward to the Roman Catholic cemetery. A macadam road was built and after five year's use the surface is fine, hard, and well cemented. The road is hilly, much used and subject to cutting by water. This road has demonstrated the excellence of this type of rock for road construction. Approximately 1,000,000 cubic yards of rock occur above an elevation of 100 feet above mean sea-level, where drainage is good. The nearness of this locality to tide water and the highways makes transportation cheap. It occurs within half a mile of the Courtenay Bay docks now under construction.

No. 4. This rock is massive, dense, and fine-grained. The exceptionally low per cent of wear and great toughness indicate that the rock is very suitable. Cut down to the level of Dufferin row from which a good face could be worked, about 15,500 cubic yards are available.

No. 5. This is a somewhat altered portion of the diabase, and in some portions it is considerably sheared. The broken character may account for the extremely low figure for toughness, which may be lower than the average. About 1,000 cubic yards were quarried from the southeast face and used for wharf ballast. There is little overburden, soil occurring only in the depressions. The Canadian Pacific Railway tracks parallel the occurrence so that it is easily accessible for transportation by rail. Charlotte Street extension forms its northern boundary and the area covers about 4 acres.

No. 6. This sample is typical of the rock underlying the highest portion of West St. John. The area chosen for this test is well known as it lies along the north side of Charlotte street opposite the Martello tower. Amygdaloidal and fragmental varieties outcrop over about 1½ acres of surface with soil cover only in the depressions in the rock. Seventy yards northwestward of Charlotte street glacial gravels occur and cover the bedrock to a depth of several feet. The tests indicate that this material is of excellent quality for road construction. The elevation of the highest part of the area is 190 feet above sea-level and transportation by wagon is down grade in all directions. Approximately 25,000 cubic yards is easily available above the level of the streets and, by increasing the depth cut, several times this amount could be obtained.

No. 7. The diabase of this locality is massive and medium-grained. Three outcrops occur above the gravels and present good faces for quarrying. The largest area is about 1½ acres in extent. Approximately 20,000 cubic yards are available above soil level from this locality. The tests indicate that the rock is of exceptionally good quality for road construction.

GRAVEL.

The country surrounding St. John city is particularly rich in sand and gravel of glacial origin, suitable for the construction of gravel roads, and for concrete work. Tests have been made of samples from deposits along Golden Grove and Loch Lomond roads, east of St. John, Manawagonish and South Bay roads and the bay of Fundy coast, west of the city. The conclusion has been reached by highway engineers that in regard to gravels in general, the mechanical tests are not as definite as for broken stone on account of the variety of materials involved. It is thought, however, that gravel having a percentage of wear of over 6 will not be suitable for any but the lightest country traffic and should not be used if better material is available. For medium heavy traffic the limiting value for gravel cannot be much higher than 3 per cent of wear. Gravel with a wear of from 3 to 6 per cent should be suitable for light country traffic.[1] The following speci-

[1] Reinecke, L., "Road Materials for 1915", Geol. Surv., Can.

Table I. Results of Tests on Bedrock from St. John, N.B., and Vicinity.

No.	Location	Owners	Development	Type of rock	Per cent of wear	French coefficient of wear	Hardness	Toughness	Cementing value	Specific gravity	Water absorbed lbs. per cu. ft.
1	St. John city, north side Rockland road at its junction with Burpee ave.	Frank Hollis, 311 Rockland road.	City quarry now in operation.	Trachyte.	4·7	8·5	19·0	14	30	2·71	0·22
2	West St. John. Area bounded on the east by Lancaster st., on the south by Charlotte st., at the west end of Rodney st.	St. John city.	City quarry now in operation.	Sandstone and shale.	9·7	4·1	17·0	14	43	2·78	0·28
3	East St. John. Hill east of reformatory.	St. John county.	Two excavations not operated at present.	Diabase	4·1	9·7	18·2	11	106	2·78	0·16
4	West St. John. In area bounded by Dufferin Row City line, Clifton st. and a street on the west side.	Miss Morgan, 382 Douglas ave., St. John.	None.	Diabase.	2·9	13·6	18·3	19	57	2·81	0·45
5	West St. John. South side Charlotte St. extension and north of Canadian Pacific Railway track, in lot east of Seaside park.	F. E. DeMille, West St. John.	One excavation along ry. track.	Altered diabase.	4·2	9·5	17·2	3	97	2·87	0·06
6	West St. John. Northwest side Charlotte st. opposite Martello tower.	Dominion Government.	None.	Amygdaloidal and fragmental diabase.	2·5	16·0	18·6	23	78	2·85	0·09
7	West St. John. East side of Sand Cove road about 1,000 feet south of Manawagonish road forks.	Richmond Cushing, Fairville, N. B., Samuel Waters, West St. John.	None.	Diabase.	3·6	11·1	18·3	15	110	2·79	0·21
8	Average of results of diabase rocks Nos. 3 to 7.				3·5	11·6	18·1	14·2	89·6	2·82	0·19

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Table II. Results of Tests on Gravels from the Vicinity of St. John, N.B.

No.	Location	Owners	Per cent of wear	French coefficient of wear	Cementing value	Specific gravity	Per cent of: Voids materials loose	Voids materials compacted	Gravel passing 3-inch screen retained on ¼-inch.	Sand passing ¼-inch screen retained on 200-mesh.	Silt and clay passing 200-mesh screen.
1	North side of Golden Grove road, 2 miles northeast of Coldbrook station.		5·0	8·0	122	2·66	28·9	20·0	52·3	41·4	5·9
2	South of Loch Lomond road, on south side Little river, ½ mile above Silver falls.	St. John city.	1·4[1]	29·2	131	2·71	36·4	25·7	25·1	74·1	0·8
3	South side Loch Lomond road at Silver falls, 200 yards east of orphanage.	S. Creighton, Loch Lomond road, St. John, N.B.	2·6	15·4	120	2·69	30·0	23·0	44·7	55·0	0·3
4	South of Loch Lomond road on east bank of Little river, 300 yards south of Little falls. Top of steep bank 100 feet above sea-level.	S. Creighton, Loch Lomond road, St. John, N.B	2·7	14·8	83	2·69	33·8	25·8	27·1	72·7	0·2
5	Northwest shore of St. John City reservoir, south side Loch Lomond road.	St. John city.	7·8	5·1	162	2·73	32·4	23·1	55·6	43·7	0·7
6	South of Loch Lomond road, on road along St. John City water main, ½ mile west of Fitzgerald lake.	J. T. N. Desmond, Loch Lomond road, St. John, N.B.	5·5	7·3	81	2·67	30·0	21·3	46·2	52·7	0·9
7	Beach extending from breakwater west St. John westward for 4,000 feet.	Dominion Government.	0·3	133·2	50	2·66	40·8	31·3	98·1	1·8	0·0
8	Manawagonish beach.	Dominion Government.	0·4	100·0	55	2·71	39·2	31·0	99·9	0·0	0·0
9	Sand and gravel cliffs extending from Sheldon point westward for 4,000 feet.	David Lynton, Sand cove, St. John, N.B.	2·4	16·7	107	2·69	33·0	23·1	62·8	35·0	2·0
10	South side Manawagonish road, 1 mile west of Fairville and 600 yards southwest of South Bay road forks	C. H. Quinton, Fairville, N.B.	4·6	8·7	172	2·68	29·5	22·1	52·5	46·9	0·4
11	Hill south of Canadian Pacific railway, one mile east of South Bay station.	A. W. Anderson.	3·2	12·5	139	2·67	32·5	23·6	43·5	55·1	1·3
12	Gravel pit 1,000 feet southeast of South Bay station, at end of Canadian Pacific siding	Canadian Pacific Railway Co.	2·6	15·4	191	2·67	29·5	20·6	52·4	45·8	1·5

[1] It was impossible to make abrasion test on this gravel according to specifications, as there was not sufficient gravel retained on ½-inch screen to make full charge; 2170 grains retained on ½-inch screen and 2830 grains passing ½-inch screen and retained on ¼-inch screen was the charge used

fications for sizes were adopted by the American Society of Municipal Improvements in 1916: "Two mixtures of gravel, sand, and clay shall be used, hereinafter designated in these specifications as No. 1 product (for top course) and No. 2 product (for middle and bottom courses).

"No. 1 product shall consist of a mixture of gravel, sand, and clay, with the proportion of the various sizes as follows: all to pass a $1\frac{1}{2}$-inch screen and to have at least 60 and not more than 75 per cent retained on a $\frac{1}{4}$-inch screen; at least 25 and not more than 75 per cent of the total coarse aggregate (material over $\frac{1}{4}$-inch in size) to be retained on a $\frac{3}{4}$-inch screen; at least 65 and not more than 85 per cent of the total fine aggregate (material under $\frac{1}{4}$-inch in size) to be retained on a 200-mesh sieve.

"No. 2 product shall consist of a mixture of gravel, sand, and clay, with the proportions of the various sizes as follows: all to pass a $2\frac{1}{2}$-inch screen and to have at least 60 and not more than 75 per cent retained on a $\frac{1}{4}$-inch screen; at least 25 and not more than 75 per cent of the total coarse aggregate to be retained on a 1-inch screen; at least 65 and not more than 85 per cent of the total fine aggregate to be retained on a 200-mesh sieve."

Remarks on Deposits.

No. 1. From Golden Grove to Coldbrook, the Golden Grove road follows a preglacial valley in which glacial material was deposited as unstratified till and as stratified outwash deposits. The sample tested was taken from the face of an excavation of unstratified material. This has been used on the Golden Grove road with fair results. It is suitable for light traffic only.

No. 2. The Loch Lomond road also follows a preglacial valley which has been partially filled with deposits of glacial origin, stratified sand and gravel being especially abundant. These deposits have been dissected by stream erosion and workable deposits are frequently exposed especially along the south bank of Little river. In one of these deposits the city has established a pit, and a face about 20 feet in height and 80 feet long has exposed a very well stratified deposit in which the sand and gravel are well sorted. The sand is used in the construction of asphalt pavements in St. John city and as a top dressing for macadam roads. This material contains too high a percentage of sand for use in the construction of gravel roads without the addition of coarser material.

No. 3. Stratified gravel forms a mound rising to a height of about 50 feet above Loch Lomond road. The mound extends along the south side of the road for about 200 yards and is about 80 yards wide. Excavations have been made on both north and south slopes. The proportion of sand to gravel is too high for best results in gravel road construction but the coarser material might be selected.

No. 4. An excavation in this deposit shows little coarse material. An overburden of soil with trees covers the sandy gravel.

No. 5. Stratified and cross-bedded gravels occur in a glacial mound between Loch Lomond road and the west end of the reservoir lake. An excavation facing the lake has exposed a good section for sampling. The per cent of wear is very high but the exceptional cementing value may offset the poor wearing quality. The material would be suitable for very light traffic only.

No. 6. Stratified sand and gravel extends for several hundred yards along the road following the St. John city water main and has been used locally for patching roads. The proportion of sand to gravel is too high for best results and should be graded for gravel road construction. An overburden of weathered material, trees and stumps, is about 2 feet in thickness.

No. 7. Sand and gravel from this beach were used in the concrete foundation of the Atlantic Sugar Refinery, St. John, completed in 1914. The material

is used by M. Long, West St. John, for the manufacture of concrete building blocks and for sidewalks. It was also used by B. Mooney and Sons, St. John, for the concrete work of Scovil Bros', building on King street, completed in 1915, The sand and gravel is partially sorted by tidal action and the thicknesses vary from point to point and from day to day in any one place. Within the tidal area there appeared at the time examined to be much more sand than gravel. Clay and silt is practically absent. The locality is easily available for transportation by water or wagon, and the Canadian Pacific Railway yards are on the flat immediately above the beach 60 feet above sea-level.

No. 8. The material along this beach is very well sorted and the sample has been taken from the gravel. Coarse sand is plentiful in the tidal area. A barrier beach of coarse gravel has been thrown up by storm waves at high tide. This portion of the beach is about three-quarters mile long. There is a platform from which vessels can be loaded at high tide, and a wagon road leading to West St. John parallels the beach.

No. 9. A cliff of stratified clay, sand, and gravel extends for about 4,000 feet westward from Sheldon point and rises abruptly to 80 feet above sea-level. On account of slumping the strata are not well exposed, and the sample was obtained from the upper portion of the cliff.

Nos. 10, 11, 12. A ridge of stratified Pleistocene clay sand and gravel encloses an oval-shaped depression about 2 miles west of Fairville. The ridge rises from sea-level to an elevation of 180 to 200 feet and the distance across the depression in a north-south direction from crest to crest of the ridge is about one mile. The base of the ridge itself is about half a mile in width. The ridge widens eastwards and the Manawagonish road follows its crest westwards from Fairville. Samples 10, 11, and 12 have been taken from different points along this ridge. It is probable that sand and gravel of the sort tested forms a large portion of the upper strata of this ridge and, therefore, satisfactory material for road construction may be had in abundance from many points in this area.

No. 10. The excavation from which the sample was taken lies at about 30 feet elevation above sea-level near the top of the ridge. This material could be improved by using a smaller percentage of sand. It has a rather high per cent of wear but excellent cementing value. This is shown in the surface of the Manawagonish road which is dusty in dry weather but nevertheless wears with a fairly smooth bed, and is one of the best roads in the vicinity of St. John.

No. 11. The locality from which this sample was taken is on the northern slope of the circular ridge of stratified sands and gravels, and an excavation has been made by the Canadian Pacific railway for ballast. The material has also been used on the road in this vicinity. These roads are dusty in dry weather but have a well cemented surface. The Canadian Pacific railway have a siding to the pit.

No. 12. A cut has been made about 50 feet deep, completely through the ridge, by the Canadian Pacific railway, and the material used for ballast. There is a siding laid through the cut, steam shovels being used for loading cars. The length of the cut is about 1,500 feet and width 80 feet.

GOLD-BEARING SERIES IN NORTHERN PARTS OF QUEENS AND SHELBURNE COUNTIES, NOVA SCOTIA.

(*E. R. Faribault.*)

The greater part of the field season of 1916 was spent by the writer in the northern part of Queens and Shelburne counties completing the geological mapping of the Indian Gardens map-area, No. 108, surveyed in 1915, and the

Caledonia map-area, No. 107, surveyed in 1914. The field work on these sheets is now completed and ready for compilation. In addition, the geological structure, partly worked out in previous years, of Whiteburn gold district, in the Caledonia map-area, was completed, and a special plan of the district on the scale of 400 feet to one inch is now ready for publication.

On September 25, the field party moved to Sable River station, Shelburne county, on the Atlantic coast, and began the mapping of the Sable River map-area, No. 109, and Lockeport map-area, No. 110, lying south of the Indian Gardens map-area. These areas are underlaid by rocks of the Gold-bearing series which is here cut by some granite intrusions and diabase dykes. In these two map-areas, gold quartz has been discovered at several places, but no mining operations have yet been undertaken. Molybdenite has been known for some time to occur at Jordan Falls, and the writer was shown some good samples of molybdenum ore which were said to be from a quartz vein prospected for gold several years ago at Louishead, Shelburne county, on land owned by W. H. Ringer. Infusorial earth was observed on Jordan river 1½ miles above lake John.

Field work was commenced on May 15 and continued until October 31. J. McG. Cruickshank, Cecil Brown, and J. C. Ells were employed as assistants and rendered efficient service.

In November, an examination was made of the tungsten deposits of Moose River, Halifax county. The mine owned by Scheelite Mines Limited, 2 miles west of the Moose River Gold Mines post-office, was reopened in July and is now producing under the management of John Reynolds. Scheelite was also found at two places in the underground workings of gold mines at Moose River; at a depth of 150 feet in a crosscut running south from the Kaulback shaft, where a quartz vein curves in a synclinal fold; and a short distance farther east, at a depth of 90 feet, in a shaft opened by George Cameron. On account of the great demand for tungsten and molybdenum for war purposes, the price of the ore of these two metals has more than doubled during the last two years. Scheelite and molybdenite have been discovered at many localities in the Gold-bearing rocks of Nova Scotia, and prospecting for these rare minerals should be encouraged.

The Caledonia map-area was reported on in the Summary Report for 1914, pages 103-116, and the Indian Gardens map-area in that for 1915, pages 186-192. Nothing need be added to these descriptions, as a result of last season's exploration, on the character, general geology, and mineral occurrences of these areas. In certain parts of the region, however, the geological structure of the Gold-bearing series was worked out in greater detail and some of the anticlinal axes and domes were more closely located. Much time was spent between lake Rossignol, Jordan Great lake, and lake John, where heavy drift, swamps, and bogs cover the surface and rock exposures are very scarce. Further information was also obtained regarding the complicated structure of certain portions of the dome of the Whiteburn gold district. As a result, the provisional description given in the Summary Report for 1915, pages 188 and 189, of the (4) Whiteburn anticline and the (5) Harlow Brook anticline requires correction. It was found that the anticline crossing Harlow brook is the western continuation of the Whiteburn anticline, and the anticline crossing Silver lake is separate from the Whiteburn anticline and lies 2 miles southeast of it.

From the dome of the Whiteburn gold mines, the Whiteburn anticline extends southwesterly across the western end of Carrigan lake, thence along the southern side of Lacy and Menchen lakes, and crosses lake Rossignol at Spark island, Sam point, and Southwest bay, whence, instead of curving southerly across Fifth, Sixth, Silver, East Jordan, and Jordan Great lakes, as reported

previously, its axis runs straight across the middle of Fifth and Seventh lakes and the southern part of Second Porcupine, and Black Duck lakes, crosses Harlow brook half a mile north of the outlet of Jordan Great lake, and Long Lake brook halfway between Martin lake and Long lake, beyond which it is cut off by granite on the West branch of Jordan river. The fold plunges westward from the dome of the Whiteburn gold mines to Spark island, and thence plunges eastward to the granite. From Southwest bay to Harlow brook the surface is covered with heavy drift and very few rock exposures are to be seen; but west of Harlow brook many large outcrops of quartzite dipping at low angles, describe broad curves on the eastern plunge of the fold, indicating the presence of a broad dome near the granite, $1\frac{1}{2}$ miles west of Martin lake on Jordan river.

The Silver Lake anticline lies 2 miles southeast of the Whiteburn anticline and runs parallel with it. On account of the scarcity of rock exposures the axis could be well located only at two places, on the western side of Silver lake and on the southeastern side of Jordan river near the West branch. It crosses Silver lake about midway of its length and extends northeasterly across the northern end of Sixth lake and the southern part of Fourth lake to the Screecher on lake Rossignol, where the fold flattens out and terminates by meeting the syncline intervening between it and the Whiteburn anticline. From Silver lake southwesterly, it crosses the northern part of East Jordan lake, the middle of Jordan Great lake near the north end of Long island, and Jordan river immediately south of the West branch, a short distance beyond which it is cut off by granite. From lake Rossignol to East Jordan lake it plunges easterly, and from there to the granite it appears to plunge westerly forming a dome in the vicinity of East Jordan lake. Gold float reported to have been found on Silver lake is probably derived from veins occurring on the eastern part of this dome.

A close study of the structure of these two anticlines and of the sequence of the rocks exposed, shows that, as a result of extensive upheaval and erosion, probably the lowest known strata of the Gold-bearing rocks are brought to the surface. The quartzites of the Goldenville formation are here underlaid by a thickness of about 1,600 feet of banded, light silvery-grey and bluish-grey, knotted, micaceous, argillaceous, and siliceous schists, similar to those occurring at about the same horizon along the first anticline south of Liverpool. These schists are best exposed on the east shore of Fifth lake, on the west side of Eighth lake, and at the south end of Jordan Great lake, where they extend towards the southwest, lying at low angles, and spread out to a great width across Rush and Grandy lakes and to lake John. Furthermore, along the axis of the folds these schists are in turn underlaid by a considerable thickness of much altered quartzites which are not exposed anywhere else in the part of the province explored by the writer. These quartzites extend all along the Whiteburn anticline from Fifth lake southwesterly to the granite, and are well exposed to the west of Harlow brook; while along Silver Lake anticline they extend southwesterly from Fourth lake to the granite, and attain a width of nearly 2 miles on the dome of East Jordan lake. They are best exposed on the southeastern side of Jordan river.

ECONOMIC GEOLOGY.

Infusorial Earth. A deposit of apparently pure, white, infusorial earth was observed in a meadow on the left bank of Jordan river, one-half mile below the West branch, at the head of the long stillwater above lake John. It can be seen only when the dam is opened and the water is quite low in lake John. The deposit probably underlies the greater part of the meadow which extends along both sides of the river for three-quarters of a mile in length and one-quarter mile in width.

Tailings from the Old Parker Douglas Stamp Mill. Concentrates panned from old tailings at the old Parker Douglas stamp mill, Whiteburn gold mines, were examined at the Mines Branch laboratory, and were found to contain: sand 60 per cent; and arsenopyrite, pyrite, ilmenite, scheelite, gold, and mercury, making up the remaining 40 per cent. The scheelite constitutes approximately 0·12 per cent, by weight, of the whole, and the gold content is 8·8 ounces, Troy, to the ton of 2,000 pounds.

DIVISIONAL REPORTS.

REPORT OF THE VERTEBRATE PALÆONTOLOGIST.

(*Lawrence M. Lambe.*)

Field Work.

The exploration of the Edmonton Cretaceous dinosaur-bearing beds of Red Deer river, Alberta, was continued during the past season by a party under George F. Sternberg. This party was the only vertebrate palæontological one in the field this year. Mr. Sternberg spent the summer of 1915 on these beds with good results and this season's work was a continuation of that of the previous year, extending the exploration downstream over an extensive area of badlands.

Mr. Sternberg left Ottawa on June 3 for Red Deer river where he remained until October 19 when weather conditions compelled him to abandon field work for the season.

Taking up the work of collecting where it was left off in 1915, due west of Rowley in sec. 19, tp. 32, range XXI, a thorough search was made over the exposures on both sides of the river for a distance of about 12 miles down the river to sec. 34, tp. 30, range XXI.

The specimens obtained belong principally to herbivorous dinosaurs, viz., trachodonts, stegosaurs, and ceratopsians. The skeleton of one large trachodont is thought to be nearly complete, but the greater part of the collection consists of parts of individual skeletons and many separate bones. Some of the specimens are in an excellent state of preservation in rather soft sandstone which can be readily removed without injury to the bones. In others a clay-ironstone incrustation makes the work of the preparator in the laboratory most difficult.

The collection is a valuable one supplementing the material we already have from the Edmonton formation. It will prove most helpful in elucidating imperfectly known forms from this horizon and it is thought to include some species not as yet described. Reference to the more important specimens of this collection will be found on page 291.

A number of photographs were taken to show the surface character of the rocks and the manner in which weather erosion has carved the beds into an endless variety of fantastic shapes. Others illustrate field methods as practised by this Survey, and some are intended to serve as a record of the position of the bones as found.

The season's collection was sent to Ottawa in twenty-four large boxes, having a total weight of nearly 12,000 pounds.

Mr. Sternberg's thanks are due to Mr. William Stauffer, whose ranch, near Morrin, lies within the area explored, for many courtesies and kind assistance accorded him and his party during the whole of the field season.

Special mention may be made of the following three specimens, in order of merit, included in last summer's collection:

Field No. 6. The greater part of the skeleton of a trachodont remarkable for its size and excellent state of preservation. The species is probably new to science.

Field No. 11. The skull and about one hundred and fifty dermal scutes of an armoured dinosaur, with vertebræ, limb-bones, and ribs. The skull in particular is well preserved and the scutes, although not found in their proper relative position to each other, will probably throw light on their general arrangement in the armature.

Field No. 9. Remains of Ornithomimus which include the whole of the fore limb and a complete hind foot, in sandstone which is easily removable. The association of the front foot with the hind foot is especially welcome.

Research and Office Work.

Some of my work which was well advanced toward the end of 1915 was finished in the early part of 1916, and other work begun this year has since been completed. It may be stated that last year, following instructions received, my report on the division of vertebrate palæontology was handed in on November 15, so that a month and a half at the close of 1915 was left to be included in this report for 1916.

Collections received from officers of the department and from outside sources have been studied and in some cases reported on.

Apart from the direction and superintendence of the work of the division as a whole, my time has been largely given to the completion of a popular guide to our fossil vertebrates, and the preparation of a memoir on the carnivorous dinosaur Gorgosaurus.

The manuscript for the "Popular guide to the exhibit of fossil vertebrates (with illustrations)," which was referred to in my summary report for 1915 as nearing completion, was ready for the printer and handed in on January 28, 1916. It consists of over one hundred and sixty pages with seventy-nine text figures.

The Guide is intended primarily for the use of visitors to the hall of fossil vertebrates and as such describes principally the specimens on exhibition. It is based on the descriptive museum labels written in popular language which accompany the exhibited specimens. By referring briefly to the salient, distinguishing characters of the classes of vertebrate animals, both living and extinct, and the relationship of these classes to each other, it brings to the attention of the reader the evolutionary changes which have taken place in the history of the vertebrata and which the specimens on exhibition serve to partially illustrate. The generally accepted classification of geological time divided into periods, is set forth in a table which includes a list of the more important types of vertebrate animals characteristic of these periods and leading from the lowest and earliest forms to the higher and later types. A classification of the various groups of vertebrates in tabular form is also given, showing the regular sequence of the primary divisions of fossil and living vertebrates from lower to higher types, with examples of some of the principal forms. The short descriptions in popular language in succeeding pages are almost exclusively of the specimens of fishes, amphibian tracks, reptiles, birds, and mammals that were on view in the hall of fossil vertebrates as a temporary exhibit.

Numbers in heavy type in the left hand margin of the text, corresponding with conspicuous numbers in the museum hall, will afford a means by which the reader can readily find any particular specimen or group of specimens referred to. An index is also provided.

This guide deals largely with the past vertebrate life of Canada and includes descriptions with illustrations of many newly discovered forms from within the confines of the Dominion, bringing together for the first time under one cover the results of many years of collecting by the Geological Survey. For this reason it should prove useful to the schools and educational institutions generally throughout the country.

The manuscript for the descriptive illustrated memoir on the Belly River Cretaceous dinosaur *Gorgosaurus libratus*, was written during the year and is

now almost ready for the printer. It consists of over one hundred pages with nearly as many illustrations for use in the text.

Early in the year a paper entitled "Ganoid fishes from near Banff, Alberta," descriptive of fish remains from lower Triassic rocks, collected by L. D. Burling at Massive on the line of the Canadian Pacific railway, 10 miles west of Banff, and by J. A. McLennan near Massive, was written and presented at the annual May meeting of the Royal Society of Canada for publication. This paper describes three new species, representing as many genera, and is illustrated by three full sized plates. The fish fauna brought to light is interesting and of stratigraphical value. Reprints of the paper for the Geological Survey ensures a wider distribution than would otherwise be obtained.

The weekly meetings of the library committee were attended as usual.

Miss E. F. Goodman has been engaged in cataloguing collections, in general museum work, and in the clerical work of the office. She has performed the duties of her position in a thorough and exemplary manner. When the public exhibition of specimens ceased after the Parliament building was destroyed by fire, Miss Goodman was able to devote a greater part of her time to the classification and arrangement of the duplicate and study collections. The principal collections catalogued by Miss Goodman during the year are as follows:

Many hundreds of the separate specimens of the 1914 field collection from the Belly River formation of Red Deer river, Alberta.

The small collection of 1914 from the Judith River Cretaceous of Missouri river, Montana, U.S.A.

The small collection of 1914 from the Oligocene of the Cypress hills, Saskatchewan.

The greater part of the available separate material of the collections of 1915 from the Edmonton and Belly River formations of Red Deer river.

Mr. A. Miles has continued the illustrative work of the division and has been most successful with the many difficult fossils drawn, most of which needed careful study to ensure a proper emphasis of essential points of structure and form. The majority of the drawings required for the illustration of the palæontological reports in hand have been made in ink line, a style well adapted for reproduction as text figures and a method of illustration in which Mr. Miles's knowledge of photo-engraving is peculiarly helpful. During the year Mr. Miles completed the remainder of the drawings for the Popular Guide, already referred to, those required for the large number of figures in the memoir on Gorgosaurus, and those forming the plates in the paper on Banff fishes, as well as a number of other drawings intended for forthcoming publications.

The employment of Mr. C. H. Sternberg as a preparator and collector ceased, at his own request, on March 31, 1916, the last day of the fiscal year. During his four years connexion with the Geological Survey, Mr. Sternberg collected principally from the Belly River and Edmonton exposures on Red Deer river, Alberta, and was most successful in his field work, adding a large amount of valuable exhibition and study material to the departmental collections.

Public Exhibits.

Before the close of 1915 and during January of the present year a number of important additions were made to the exhibits in the hall of fossil vertebrates. These are as follows:

The skulls (plaster restorations) of *Pithecanthropus erectus* and *Eoanthropus dawsoni* (Piltdown man), and two British Columbian Indian skulls, supplementing the exhibit illustrating the evolutionary history of man.

A cranium, with lower jaw, of Mammoth, and two tusks of Mammoth, from the Pleistocene gravels of Yukon. (Acc. No. 106.) Added to the Proboscidean series.

A neck ring of transverse scutes, without keels, of a Belly River Cretaceous stegosaur (armoured dinosaur); collection of 1914 from Red Deer river.

A very large skull (nasal portion and lower jaw restored) of the horned dinosaur Chasmosaurus; collection of 1913 from the Belly River formation of Red Deer river.

A complete skull of the hooded dinosaur Stephanosaurus; collection of 1915 from the same geological horizon.

On February 4, the day following the destructive fire in the Parliament building, acting under instructions prior to the occupancy of the Victoria Memorial Museum building by the House of Commons and the Senate, all the exhibited specimens were moved to the south end of the hall of fossil vertebrates where they are now not accessible to the public.

Laboratory.

Good progress has been made in the laboratory during the year in the preparation of a number of important specimens which will be placed on exhibition when the hall of fossil vertebrates is again available for use.

To C. M. Sternberg was assigned the preparation of the practically complete skeleton of the Pleistocene horse, *Equus scotti*, acquired by the Survey in 1915. This specimen has been removed from the matrix and strengthened where required. It will later be set up as an open mount for exhibition. Mr. Sternberg also advanced the Gorgosaurus skeleton to the stage prior to the final exhibition one into which, however, it cannot now be carried under present circumstances. He also mounted the 1913 skull of *Chasmosaurus belli* which has since been exhibited.

G. F. Sternberg, before leaving for the field successfully removed from hard rock the hind limb and most of the head of a trachodont of large size collected from the Edmonton formation in 1914; also from similar rock and belonging to the same collection, two skulls of a remarkably small species of trachodont. Both these skulls are ready for study and exhibition. Since returning from the field he has removed the matrix from the under surface of the 1914 skull of *Chasmosaurus belli*, preparatory to its being figured, and has given some time to material of his 1916 collection.

C. H. Sternberg during the three months prior to his leaving the department, prepared most of the anterior half, including the skull (since exhibited) of a rather complete skeleton of Stephanosaurus collected from the Belly River formation, Red Deer river, in 1915.

Other work in the laboratory was entrusted to L. Sternberg and G. Lindblad, the latter of whom assisted in the field on Red Deer river during the past summer.

Additions to the Vertebrate Palæontological Collections during 1916, and the Closing Six Weeks of 1915.

Collected by Officers of the Department.

Sternberg, George F., and party:

Reptilian remains, principally dinosaurian and crocodilian, from the Edmonton formation on Red Deer river, Alberta. (Received at Ottawa, Nov. 11, 1916.) Acc. No. 115. The determinations as given below

are tentative field ones only. The enumeration with field numbers is nearly in the order in which the specimens were collected.

(1) Trachodont: the specimen, representing a large individual, includes the greater part of the pelvic arch with four dorsal vertebræ, and one hind limb lacking only a part of the foot; from about 7 miles west of Rowley, sec. 17, tp. 32, range XXI, on the east side of the river, about 150 feet above its summer level; June 26.

(2) Trachodont: the scapula and humerus well preserved, of a large individual; found near No. 1 at about 140 feet above the river; June 26.

(3) Ornithomimus: the greater part of a hind foot with the outer toes in place; from about 7 miles west of Rowley in sec. 18, tp. 32, range XXI, on the west side of the river, about 35 feet above water-level; July 3.

(4) Trachodont: two metatarsals with the astragalus and calcaneum of one individual; from about 7 miles west of Rowley, in sec. 17, tp. 32, range XXI, on the east side of the river, and about 145 feet above water-level; July 7.

(5) Crocodile: a large number of dermal plates of one individual, with probably a part of the skull; about 7 miles southwest of Rowley, in sec. 33, tp. 31, range XXI, on the east side of the river and about 50 feet above the water-level; July 22. Crocodilian remains are rather rare in the Edmonton formation.

(6) Trachodont of large size: all of the skeleton except the right ilium, the greater part of the tail, and a few of the foot bones; it is not certain that the premaxillaries and the predentary are present; found 7 miles west of Morrin, in sec. 16, tp. 31, range XXI, on the west side of the river, about 90 feet above water-level. The bones, which were somewhat scattered, are in an excellent state of preservation making the specimen a valuable one for study purposes and suitable for an open mount. Most of the elements from the sides of the skull, which is nearly 4 feet long, were found disarticulated.

(7) Trachodont: part of the skeleton of a small individual, including a femur, tibia, ilium, pubis, fibula, and some bones of the fore limb, besides several ribs and vertebræ, etc.; from 6 miles west of Morrin, in sec. 15, tp. 31, range XXI, on the east side of the river, about 35 feet above water-level; July 25.

(8) Armoured dinosaur: the terminal armour of the tail complete. Well preserved and of large size, 21 inches long, 17 broad, and 11 high; discovered about 7 miles west, and slightly north of Morrin, in sec. 28, tp. 31, range XXI, on the east side of the river, about 50 feet above water-level; September 14.

(9) Ornithomimus: a well preserved specimen in soft sandstone consisting of the pectoral arch and complete right fore limb, left humerus, complete right hind foot, part of the left, a number of bones of both hind limbs, and some undetermined parts; 9 miles southwest of Morrin, in sec. 34, tp. 30, range XXI, on the west side of the river, about 100 feet above the water-level; September 11.

(10) Trachodont: very well preserved bones of one individual, viz., the ulna, radius, two or three metacarpals, and several phalanges; found near No. 9 on the same day, about 65 feet above the river.

(11) Armoured dinosaur: a skull in an excellent state of preservation, with several limb bones, ribs, vertebræ, and about one hundred and fifty dermal plates; possibly the lower jaw may not be present; from about

8 miles southwest of Morrin, in sec. 3, tp. 31, range XXI, on the west side of the river, at an elevation of 90 feet above water-level; Sept. 11.

(12) Trachodont: some well preserved bones of a very small individual including a maxilla, dentary bone, humerus, femur, fibula, and several other bones not yet determined; found associated with No. 11.

(13) Armoured dinosaur: the greater part of the skull, well preserved, with the first transverse ring of neck scutes complete. The more anterior portion of the skull has weathered away and the lower jaw is missing; from about 7 miles west of Morrin, in sec. 10, tp. 31, range XXI, on the west side of the river about 75 feet above water-level; Sept. 26. This specimen represents an individual larger than No. 11.

(14) *Anchiceratops:* represented principally by the complete left half of the parietal crest, with parts of the right half; discovered about 9 miles southwest of Morrin, in sec. 33, tp. 30, range XXI, on the west side of the river, about 150 feet above water-level, October 14. In the skull proper of this horned dinosaur, the supraorbital horns are preserved but not the nasal one.

In addition to the above fourteen individual specimens there are included in the collection between seventy-five and one hundred separate bones representing the varied fauna, principally dinosaurian, of these Edmonton beds.

Burling, L. D.:

Fish remains, belonging to the genera Cœlacanthus and Elonichthys, from rocks of lower Triassic age at Massive, 10 miles west of Banff, Alberta. Acc. No. 105. Since described by Lambe under the names *C. banffensis* and *E. cupidineus*, Trans. Roy. Soc., Can., vol. X, 1916.

McLearn, F. H.:

A vertebral centrum with decidedly concave ends and deeply excavated sides, length $1\frac{8}{10}$ inches, maximum breadth $2\frac{1}{10}$ inches, height $2\frac{1}{3}$ inches; from Athabaska river, west bank, opposite Ironpoint, La Biche shales; July 15. Field No. 51.

Fish remains consisting of scattered amphicœlous vertebral centra and fragments of bones of the head, on the surface of a piece of limestone, from the lower part of La Biche shales (Cretaceous), Athabaska river, Alberta, 5 miles above Upper Pelican wells; July 15. Field No. 54, Acc. No. 114.

Fish remains consisting of jointed fin rays and scattered cranial fragments with portions of jaws showing indications of minute pointed teeth, preserved in shale, from the lower 140 feet of La Biche shales, Athabaska river, Alberta, just above Stony rapid, on west bank; July 20. Field No. 65, Acc. No. 114. From the same locality two vertebral centra found apart from each other, one, 3 inches in diameter, and apparently referable to an Ichthyosaurian reptile, the other, about $1\frac{3}{4}$ inches in diameter, with Ichthyosaurian characters suggested.

A compressed mass of scales, fragments of bones, teeth, etc., of fish in a fine sandstone matrix; Athabaska river, east bank at Stony rapid; lower part of La Biche shales; July 20. Field No. 66, Acc. No. 114.

A piece of rusty brown sandstone bearing the remains and imprint of a bone with sculpture which resembles that of the type (shield) of *Acipenser albertensis* Lambe, of the Belly River formation of Red Deer river, Alberta; Athabaska river, east bank, about $2\frac{1}{2}$ miles below Stony rapid; Pelican sandstone; July 22. Field No. 69, Acc. No. 114.

A caudal vertebra $2\frac{1}{2}$ inches in diameter, tentatively referred to an Ichthyosaur, from the top of the Pelican sandstone (Cretaceous), Athabaska river, 8 miles below Stony rapids; July 24. Field No. 72, Acc. No. 114.

De Schmid, Hugh:

Two phosphatic rock fragments holding bone structure from Sundance canyon, Banff, Alberta. Acc. No. 107. Rocky Mountain quartzite (Upper Carboniferous).

Phosphatic rock fragments, holding Elasmobranchian remains referred tentatively to the genus Lissoprion, from Sundance canyon, Banff, Alberta. Phosphate horizon of the Rocky Mountain quartzite, Upper Carboniferous (top of Upper Pennsylvanian); July 1916. Acc. No. 109. Throughout the rock fragments are scattered remains of what is evidently calcified cartilage showing structure. Of particular interest are teeth closely succeeding each other on portions of a curved basal shaft suggestive of a spiral as described by Hay in *Lissoprion ferrieri* from Upper Pennsylvanian deposits near Montpelier, Idaho, U.S.A. (Proc. U.S. Nat. Mus. vol. 37, 1909). From the same rock surface and less than a foot from each other Mr. de Schmid obtained well preserved, minutely denticulated, large sized teeth in a uniserial row, with indications of a curved basal shaft, and weathered remains of about fourteen, smaller sized teeth, in close succession on a curved shaft over 7 inches in length. The larger sized teeth are nearly 2 inches in length, and over three-fourths of an inch broad near the base. They are narrowly lenticular in cross section, rather straight, pointed above, sharp-edged, with about twenty serrations in a space of a quarter of an inch on any part of the edge observed. Their sides are longitudinally striated. The smaller sized teeth average a little over half an inch in breadth below. They have the same general shape as the larger ones but in none of them is the full length preserved, the upper pointed portions being destroyed and with them the sharp lateral edges which probably were denticulated. It is possible that the above teeth belong to a single spiral, but on this point the rock fragments themselves and the data received as to the relative position of the two groups of teeth to each other, afford no conclusive evidence.

A few pieces of phosphatic rock, holding calcified cartilage and some slightly curved, pointed, longitudinally grooved fish teeth, from Spray falls, Bow river, Banff, Alberta. Phosphate horizon, Rocky Mountain quartzite (Upper Carboniferous). Acc. No. 109.

Presented.

Allan, J. A., Edmonton South, Alberta:

Bone fragment in limestone of supposed Jurassic age from immediately below black shale in Jura creek, Exshaw, Alberta. Acc. No. 108.

Coulthard, R. W., and Ponton, G. M., Calgary, Alberta (through D. B. Dowling):

Cycloid fish scales preserved in arenaceous argillite from the St. John shales (Cretaceous), 30 miles above Tar island, Peace river, Alberta. The scales occur numerously throughout the rock fragments and are sufficiently well preserved to show very close set, fine, concentric lines of growth, and in some of them relatively coarse parallel grooves crossing the free portion of the scale. The scales vary in size up to a maximum diameter of half an inch. Acc. No. 104.

Johansen, Frits, Canadian Arctic expedition, 1913–1916:
Portion of molar tooth of Mammoth, found at recently deserted Eskimo camp at Collinson point, Alaskan Arctic coast. Acc. No. 112.

Purchased.

Cairnes, D. D., Ottawa, through:
A worn Mammoth molar from Haggart creek, Duncan Creek mining district (upper Stewart river) Yukon. This is the only vertebrate bone found so far on this creek, and the first one found in this district. Since this discovery a piece of tusk has been found on Duncan creek and a large tooth on the upper part of Minto creek. This district is notable for the absence of vertebrate remains. In the Lower Stewart River district such remains abound along Thistle creek. Acc. No. 103.

Mammal remains from the Pleistocene gravels of Yukon, purchased in Dawson through D. D. Cairnes. These specimens, together with those purchased in 1915 and mentioned in the Summary Report of that year, page 198, constituted the bulk of what was known in Dawson as the "Bonanza Saloon" collection. These Yukon specimens acquired this year, Acc. No. 110, and received at Ottawa on October 21, are as follows:

Small skull of *Elephas primigenius*, Blumenbach, with small tusks and teeth (?1st and 2nd true molars) in each side of upper jaw; no lower jaw.
Femur of mammoth, 41 inches long.
Femur of mammoth, longer than the above with distal one-third of length missing, and head sawn off.
Two tibiæ of mammoth, probably a pair ; each 25 inches long.
Ulna, with proximal end of radius, 35½ inches long.
Atlas of mammoth.
Rib fragment of mammoth, 23 inches long and 3 inches broad.
Very small tusk of mammoth, complete, 16½ inches long and 1⅞ inches in diameter at base.
Skull of *Symbos tyrelli*, Osgoode (brain case and horn cores). Measures 23½ inches from tip to tip on curve of horn cores.
Bison alleni, Marsh; back part of cranium with horn cores and right maxilla with two last molars; 38⅜ inches from tip to tip of horn cores measured in a straight line.
Left nasal of Bison which may belong to the above specimen.
Cervical vertebra of Bison sp.
Lower jaw of *Equus* sp. with teeth except the first left, and all right incisors. Old male.

REPORT OF THE INVERTEBRATE PALÆONTOLOGIST.

(*E. M. Kindle.*)

Field Work.

The field work of this division has been limited to a few short collecting trips and to completing work undertaken during the preceding field season.

During the month of May Miss A. E. Wilson spent two weeks collecting from the Ordovician rocks of northern and central New York. The resulting collection from the New York type localities will be of service in the determination

of fossils from similar horizons in Ontario which are being studied. A few days were also spent by Miss Wilson later in the season in making a collection from the excellent Ordovician section at Rockland, Ontario.

Early in May I spent a few days studying the stratigraphy and faunas of the Ordovician limestones of the Kingston district, at the request of Prof. B. M. Baker of Queens university who was engaged in the preparation of a geological map and report dealing with the Kingston region. The results of this work have been incorporated in a report on the Ordovician stratigraphy of the region, which, together with a report on the characteristic fossils of the several formations found near Kingston, is to be published with Prof. Baker's map and report on the geology of the Kingston district. Another short field trip was made in company with Mr. L. Reinecke for the purpose of studying certain sections in the Kemptville district in Ontario.

I spent about seven days early in the season in completing, with the assistance of Mr. E. J. Whittaker and Dr. Kirtley Mather, the survey of a bottom section across lake Ontario between Wellington, Ontario, and Oswego, New York. Bottom samples were taken and dredging carried on up to depths of 630 feet in the course of this work. The field work in connexion with this lake bottom investigation was completed by E. J. Whittaker who spent about one month in sounding and dredging work in the lake waters of the Hamilton and Toronto districts.

The relationship of these lake investigations to stratigraphic palæontology may not be evident to all readers of this report. For this reason the following brief statement is offered regarding the two classes of investigation into which palæontological work naturally divides itself.

Palæontological work may be divided into two classes, biological and stratigraphical: the former deals chiefly with the biological and systematic study of fossils; the latter deals with the faunal and formational relations of fossils and uses them in identifying or correlating the same horizons over wide areas. The stratigraphical palæontologist is concerned chiefly with the relationship of faunas to the formations holding them and with the various factors affecting their composition, modification, and persistence through long or short periods of time. Upon his knowledge of these factors will depend in large measure his ability to reach sound conclusions in questions relating to correlation. The influence on faunas of factors such as the character of the bottom materials, depth of the seas and lakes, salinity, and others can be determined best through the study of the environment and composition of living faunas.

In order to get a clear conception of the influence of these and other factors which must have affected ancient faunas precisely as they do modern ones, I have aimed in the Lake Ontario investigation to ascertain the conditions under which the present fauna of the Great Lakes lives, particularly its bathymetric limits and modifications and the conditions of sedimentation now in operation.

Office Work.

Early in the year it became necessary to box and store all of the collections that were on exhibition in the Invertebrate hall of the Museum. These collections which comprise the types and the best material in the old collections will have to remain inaccessible until the Museum is again available for museum purposes.

The office work has included the preparation of the usual number of special reports on fossils required by various members of the Survey. A number of small collections of fossils have also been determined for individuals who have sent in fossils for identification.

Considerable progress has been made in the study of the collections of fossils made by L. D. Burling and myself in the Rocky mountains during the summer of 1915.

The study of the large collection of bottom samples from lake Ontario has occupied a portion of my time. E. J. Whittaker has prepared maps of the portions of the lake bottom which have been studied. Mr. Whittaker has also prepared a bathymetric check-list of the marine shells of the Atlantic coast of Canada. The remainder of his time has been occupied with the preparator's work of the division.

Miss A. E. Wilson has continued the cataloguing of current accessions and making a card index of the old invertebrate collections, assisted by Miss E. M. Liddle and W. Cross. The connexion of Mr. Cross with the division was terminated by his enlistment. Miss Wilson has also devoted a considerable amount of time to the determination of Ordovician fossils in connexion with the preparation of a report on Ordovician fossils which is mentioned below.

The work undertaken by this division during the year has included preparation of three reports intended primarily to aid the layman and the student who may wish to take up the study of fossils. In one of the reports a brief and elementary statement of the broader features of palæontology has been prepared for publication in a revised edition of the manual of instruction for Boy Scout masters. Another report written for the layman, which has been prepared in compliance with the wishes of the Department of Parks, is "An Introduction to the fossils of the Rocky Mountains park." This report aims to make intelligible and interesting to the man without geological training some of the larger features of ancient world life as it is illustrated in the fossils found in the Canadian Rockies. A third report prepared by this division is designed to aid the university student in becoming acquainted with the characteristic Ordovician fossils of Ontario. This report was undertaken at the invitation of the Ontario Bureau of Mines in connexion with work on the areal geology of the Kingston district by the Ontario Bureau of Mines. Other reports which have been prepared and are ready for publication are: "Recent and fossil ripple-mark" and a "Bathymetric check-list of the marine invertebrates of the Atlantic coast of Canada with an index to Whiteaves' catalogue."

The work which has been published by members of the division during the year is indicated in the following list:

Publication.

Burling, L. D.—

New data on the stratigraphy of the pre-Palæozoic and later rocks in British Columbia. Bull. Geol. Soc. Am., vol. 27, 1916, pp. 62-63.

A cheap rock polishing machine. Science, n.s., vol. 43, 1916, p. 466.

Ellipsoidal lavas in the Glacier National Park, Montana. Jour. Geol., vol. 24, 1916, pp. 235-237.

Notes on the stratigraphy of the Rocky mountains, Alberta and British Columbia. Geol. Surv., Can., Sum. Rept., 1915, pp. 97-100, 1916.

Pædeumias and the Mesonacidæ, with description of a new species having at least 44 segments, from the Lower Cambrian of British Columbia. The Ottawa Naturalist, vol. 30, 1916, pp. 53–58, pl. I.

Increasing depth of focus with the swing back. Science, n.s., vol. 44, 1916, pp. 497-498.

The Albertella fauna located in the Middle Cambrian of British Columbia and Alberta. Am. Jour. Sc., 4th ser., vol. 42, 1916, pp. 469-472.

Kindle, E. M.—

Fossil collecting. Ottawa Naturalist, vol. 29, 1916, pp. 117-124.

Bottom control of marine faunas as illustrated by dredging in the bay of Fundy. Bull. Geol. Soc. Am., vol. 27, 1916, pp. (Abstract).

Bottom control of marine faunas as illustrated by dredging in the bay of Fundy. Amer. Jour. Sc., vol. 41, 1916, pp. 449-461, figs. 1-3.

Notes on Devonian faunas of the Mackenzie River valley. Amer. Jour. Sc., vol. 42, 1916, pp. 246-248, fig. 1.

Small pit and mound structures developed during sedimentation. Geol. Mag., vol. 3, 1916, pp. 542-547, plate 13.

Report of the stratigraphical palæontologist: Geol. Surv., Can., Sum. Rept., 1915, pp. 198-205.

Additions to the Invertebrate Palæontological Collections During 1916.

Collected by Officers of the Department.

Bruce, E.L.—

A collection of Ordovician fossils from Amisk and Namew lakes, Sask. Access No. 320.

Cairnes, D. D.—

One coiled cephalopod from the Mesozoic (Jura-Cretaceous) in Wheaton area, southern Yukon. Access. No. 336.

Cameron, A. E.—

A collection of Palæozoic fossils from north shore of Great Slave lake and Hay river, N.W.T. Access. No. 344.

Camsell, Chas.—

A collection of Devonian fossils from Peace and Slave rivers, northern Alberta. Access. No. 334.

Davis, N.B. (per Keele, J.)—

Pleistocene fossils from Souris valley at Shand, Sask. Access. No. 330.

De Schmid, H. S.—

A collection of Carboniferous fossils from Rocky Mountains Park. Access. No. 339.

Drysdale, C. W.—

Fossils of Palæozoic and Mesozoic age from Sawback mountain, Slocan mining division, and from Bridge River area, Lillooet mining division, B.C. The Palæozoic fossils in this collection are from metamorphosed beds and consist chiefly of crinoid stems. Access. No. 333.

Ells, S. C.—

A collection of fossil shells representing two species of gasteropods from the Cretaceous tar sand of McMurray, Alberta. Access. No. 347.

Harvie, R. (See Knox, J. K.)—

A small collection of Utica fossils from the drift at Dows lake, Ottawa. Access. No. 329.

Hayes, A. O.—

A collection of Devonian fossils from the Nictaux-Torbrook district, N.S. Access. No. 331.

Ingall, E. D.—
Two pieces of fossiliferous Ordovician rock from gas wells at Bourget, Ont. Access. No. 316.

Keele, J. (See Davis, N.B.)—

Kindle, E. M.—
A collection of fossils from the Black River group at Kingston and vicinity. Access. No. 328.

Kindle, E. M. and Whittaker, E. J.—
Bottom samples and freshwater shells from lake Ontario. Access. No. 340.

Kindle, E. M. and Wilson, A. E.—
Fossils from the Trenton and Black River beds at Rockland, Ont. Access. No. 332.

Knox, J. K. (per Harvie, R.)—
A collection of Devonian fossils from Wolfe county, Que. Access. No. 322.

McLearn, F. H.—
Seven trays of Cretaceous fossils including large ammonites, pelecypods, etc., from Athabaska river, Alberta. Access. No. 337.

MacVicar, John.—
A collection of Mesozoic fossils from Smoky river and northern Alberta. Access. No. 341.

Nichols, D. A.—
Carboniferous fossils represented by 3 excellent specimens of blastoids (*Troostocrinus*?) from mountain southwest of mount Robinson, B.C., and two blastoids from Frank, Alberta. Access. No. 342.

O'Neill, J. J.—
A collection of fossils including Quaternary shells and Palæozoic corals from the North West Territories, Arctic coast, and islands east of Mackenzie River delta. Canadian Arctic expedition. Access. No. 335.

Rose, B.—
A piece of Carboniferous crinoidal limestone from near Frank, Alberta, Access. No. 318.

Whittaker, E. J. (See Kindle, E. M.)—
Several thousand specimens of Quaternary freshwater shells from Mackay lake, Ottawa, and samples of the several types of bottom in the lake. Access. No. 343.

Williams, M. Y.—
A collection of Silurian fossils from Manitoulin islands, western Ontario and western New York. Access. No. 345.

Wilson, A. E. (See Kindle, E. M.)—
A collection from the Ordovician of Watertown and Trenton Falls, N.Y., and Devonian fossils from Schoharie valley, N.Y. Access. No. 338.

Acquired by Presentation.

Beharriell, F. J.—
A piece of fossil coral from the Onondaga of Culross township, Bruce county, Ont. Access. No. 327.

De Schmid, H. S.—
Ice crystal marks on clay from Honiton, England. Access. No. 350.

Ferrier, W. F.—
A collection of Devonian, Carboniferous, and Mesozoic fossils from near Blairmore, Alberta, including a new pelecypod and some exceptionally fine fossils. Access. No. 346.

Foerste, A. F.—
A slab of Ordovician limestone with peculiarly pitted surface, from southern Ohio. Access. No 348.

Godsal, F. W.—
A collection of fossils from Windsor mountain, Pincher Creek district, Alberta. Access. No. 321.

Middlebrook, John—
A collection of Devonian fossils from drift near New London, Ont. Access. No. 319.
A collection of trilobites from the Hamilton drift at London, Ont. Access. No. 324.

Miller, H. E.—
Block of timber bored by Teredo from Northumberland strait, Prince Edward Island. Access. No. 349. Accompanied by dates within which the boring was done.

Acquired Through Exchange.

Crozel, G.—
A collection of Devonian fossils from the north of France. Access. No. 325.

Greger, D. K.—
Three fossil corals from Iowa and Missouri. Access. No. 326.

Hibbard, R. R.—
A collection of fossils from Hamilton shales, at Cazenovia and Ebenezer, N.Y. Access. No. 317.

PALÆOBOTANY.

(*W. J. Wilson.*)

On account of prolonged illness I have not been able to do any field work during the year, so that the work in palæobotany has consisted of cataloguing and arranging specimens in new cases, and in studying and naming collections brought in by the field men.

A number of small collections made in 1915 were submitted to Dr. F. H. Knowlton of Washington for final determination. Dr. Knowlton kindly sent the following notes:

"Lot 320. Hazelton-Aldermere area, British Columbia. Collected by J. D. MacKenzie.
Sequoia, apparently *S. langsdorfii* (Brongn) Heer, 6 specimens.
Betula sp. ? 2 specimens.
This is certainly not Jurassic, and I doubt if it is even Cretaceous. It appears to me to be lower Tertiary.

Lot 321. Northeast of Takla lake, British Columbia. Collected by C. Camsell. Several species of dicotyledons not known to me. They are too fragmentary for certain identification.

Lot 322. Bankhead coal mine, Alberta. Collected by J. A. McLennan.
Asplenium dicksonianum ? Heer, fragmentary.
Cladophlebis falcata var. Fontaine ? 5 specimens.
Fragments of *Equisetum?*
This appears to be Kootenay in age.

Lot 323. Anthracite coal mine, northeast of Anthracite station, Alberta. Collected by J. A. McLennan.
Stems, not determinable.
Cladophlebis falcata ? var. Fontaine; *Equisetum* sp.
Dioonites borealis Dawson ? fragmentary.
Asplenium dicksonianum Heer
Sequoia gracilis ? Heer
This material is not very well preserved but appears to be Kootenay in age.

Lot 324. Draw just north of Roche Miette, one mile south of Pocahontas, Alberta. Collected by J. A. McLennan.
Asplenium dicksonianum Heer. 15 specimens
Cladophlebis heterophylla Fontaine
Sequoia smittiana Heer. 5 specimens
Cyparissidium gracile Heer
Ginkgo digitata Heer. 8 specimens.

"With the possible exception of the Cyparissidium, all these forms have been found in the Kootenay, and I have no hesitation in referring lot 324 to this age.

"I have looked over the specimens rather hastily and append herewith the results of my study. The only lots about which I am in doubt are 320 and 321. The field determination would make lot 320 probably Jurassic or early Cretaceous. It is certainly not Jurassic, nor can it be as early Cretaceous as Kootenay—in fact I doubt if it is even Cretaceous. If I am correct in identifying the conifer as *Sequoia langsdorfii* it is more likely to be lower Tertiary. Lot 321 contains a number of quite fragmentary dicotyledons that I am not able to identify, at least in the time at my disposal. This may be Cretaceous, but if so it is well up in the Cretaceous. The other lots all appear to be Kootenay in age."

C. W. Drysdale during the past summer made a small collection of fossil plants from the Bridge River area, Lillooet mining division, British Columbia, Field Nos. B 35-78.

These plant remains are in a somewhat arkose sandstone and are consequently poorly preserved. They consist mostly of fragments of stems and cycadaceous leaves and two small specimens B-62 and B-55 that may be the impressions of fruit. There is one fragment of a leaf B-36 about 8 cm. long and 2 cm. broad which has most of the characteristics of *Zamites megaphyllus* (Phillips) as described by Seward and Knowlton. Unfortunately it is incomplete at the base so that its attachment to the rachis is not shown. Knowlton mentions that this species occurs with others in the Cape Lisburne area, Alaska, and points out that the age of the rocks is undoubtedly Jurassic belonging either to the upper part of the middle Jurassic or the extreme lower portion of the upper Jurassic. As far as the Bridge River area specimens indicate anything, they point to a Jurassic age for that area, but they are altogether too fragmentary and poorly preserved to base definite conclusions on.

Mr. J. MacVicar brought in a number of fossil plants from coal claims on Smoky river and other places in northern Alberta. These specimens are well preserved in dark shale and consist of ferns, cycads, conifers, etc., and from a hasty examination seem to belong to the Kootenay formation.

Additions to the Palæobotanical Collections During the Year 1916.

Acquired through Officers of the Survey.

Drysdale, C. W.—Fossil plants from Bridge River area, Lillooet mining division, B.C. Access. No. 126.

MacVicar, John.—Mesozoic fossil plants from Smoky river, and northern Alberta. Access. No. 128.

Sternberg, Geo. F.—Section of a tree from the Edmonton formation, 7 miles west of Morrison, Red Deer river, Alberta. Access No. 127.

Wilson, W. J.—A large number of fragmentary specimens of fossil plants from the Fern Ledges, Lancaster, St. John county, New Brunswick. Collections of the years 1880-1891. Access. No. 129.

I again thank Dr. F. H. Knowlton of Washington who kindly examined and named collections of British Columbia and Alberta Mesozoic fossil plants for me.

MINERALOGY.

(*Robt. A. A. Johnston.*)

Office and Laboratory.

The work carried on in the division of mineralogy during the past year has been of the same general character as that undertaken in previous years. There has, however, been a marked increase in the number of inquiries regarding Canadian mineral occurrences, more particularly those of economic interest. The number of specimens received on which expert advice was desired has reached a total of over five hundred and fifty, representing an increase of over 80 per cent over those received in 1914-15. The lack of laboratory facilities has been a serious detriment to the work and to add to the difficulty the division was obliged to give over its small laboratory quarters when the building was in the main taken over by the Dominion Government for legislative purposes following the destructive fire in the Parliament building in February last. These conditions have necessitated the improvisation of various expedients for carrying on the work and while good progress has been made in spite of these handicaps it is not to be denied that more satisfactory results would be attainable under more favourable circumstances, since the examination of many materials of undoubted importance and interest has had to be indefinitely deferred.

During the year a large number of new Canadian mineral occurrences have been recorded. These will receive attention in a supplement to "A list of Canadian mineral occurrences," Memoir 74.

Miss F. H. B. Richardson in addition to discharging the routine clerical work of the division has rendered excellent service in the recording of mineral occurrences and other matters.

Museum.

Early in the year it had been decided to arrange an exhibit of Canadian economic minerals in the west wing hall of the Museum. Temporary cases which had been ordered were nearly ready for delivery and good progress had been made with the selection of materials when the Museum building was taken over for legislative purposes and the plan had to be abandoned. The occupation of the building by the Senate and House of Commons necessitated the dismantling and dismounting of the exhibition cases in the west centre hall together with the packing and removal of all specimens either on exhibition or in storage on the ground floor. Diligent application on the part of members of the division coupled with the cordial co-operation and assistance of members of the field staff and others enabled this to be done in a very short time and with a minimum of inconvenience and loss. By reducing working space it was found possible to store much of the museum material in the building, while some of the heavier specimens had to be stored elsewhere.

During the year the mineral collections have received a number of interesting accessions and in this connexion attention may properly be drawn to some of those from extra-territorial localities. A small collection received from the Geological Survey of West Australia contains examples of rare tungsten and tantalum minerals; a somewhat larger collection received from Mr. J. Terry Duce, Bureau of Mines, Denver, Colorado, U.S.A., contains a number of fine specimens of tungsten, tellurium, and vanadium ores; a collection received from Professor A. Pelloux, Placenza, Italy, contains a number of interesting Italian minerals; and Mr. Shimmatsu Ichikawa of Kitashinjo-mura, Imatate-gun, Fukui-ken, Japan, has presented the Museum with a fine suite of Japanese specimens, embracing amongst others a series of finger rings prepared in various models from quartz crystal. The utility of having foreign specimens in the collections cannot be overestimated as they have frequently been of the greatest assistance in solving problems in classification among Canadian specimens.

The following is a list of accessions for the year:

Donations.

Mr. C. J. Brown, per D. D. Cairnes.—Wolframite pebbles from Canadian creek, a tributary of Britannia creek, Dawson mining division, Yukon.

Mr. P. E. Crane, per C. W. Drysdale.—Opal; primary bornite and chalcopyrite with magnetite and one specimen of Mother Lode ore showing sphalerite surrounded by chalcopyrite and containing magnetite, Mother Lode mine, Deadwood, B.C.

Mr. J. Terry Duce, Bureau of Mines, Denver, Colorado, U.S.A.—Ferberite, Conger mine, Primos Chemical Company, Boulder county; cerargyrite, Robert E. Lee mine, Leadville, Lake county; roscoelite in sandstone, San Miguel county; roscoelite in sandstone, Frenzel, San Miguel county; sylvanite, Beacon Hill, Teller county; rhodochrosite with fluorite, Saguadre county; hinsdalite, Lake City, Hinsdale county; sylvanite, John Jay mine, Boulder county; roscoelite, Eldorado county; hubnerite, Little Dora mine, San Juan county; tellurium, Vulcan mine, Gunnison county; vanadinite, Wood mine, Gilpin county, Colorado,

Geological Survey of West Australia, Perth, West Australia.—Pilbarite. Wodgina; stibiotantalite, Bunbury Gully, Greenbush; obsidianite, West Australia.

Mr. Ellwood Haynes, Kokomo, Indiana.—Two specimens of "Stellite" a chromium-cobalt high speed alloy.

Mr. W. F. Jennison, Truro, N.S.—Chromite, Cuba.

Mr. John McMillan, Glen Morrison, N.S.—Manganese ore from Glen Morrison, Cape Breton county, N.S.

Mr. A. G. McDonald, Kamloops, B.C.—Rhodonite, Thompson river, 80 miles north of Kamloops, B.C.

Mr. Jas. McEvoy, Toronto, Ont.—Stibnite, Lake George, York county, N.B.

Dr. Paul J. Moloney, Cornwall, Ont.—Specimen of flexible peat, con. 7, Cornwall tp., Stormont county, Ont.

Late Mr. T. H. Nellis, per W. McInnes.—Crystals of smoky quartz superposed upon an incrustation of greyish white calcite crystals, Gemmill or Nellis mine, Hull township, Ottawa county, Que.

Professor A. Pelloux, Chief d'Etat Major de la Division Militaire, Placenza, Italy.—Sulphur and aragonite, Girgenti; phosgenite, Monteponi, Sardinia; sulphur with tar, Formignano, Romagna; sulphur on galena, Masua, Sardinia; sulphur, Fabriano, Marche; harmotome and stephanite, Giovanni Bonu mine, Sarrabus, Sardinia; fibroferrite, Le Cetine di Cotormiano, Siena; spangolite, Arenat, Sarol; brugnatellite with brucite, Monte Ramazzo Borzoli, Liguria.

Mr. Jas. B. Perkins, Lytton, B.C.—Disseminated molybdenite in granitic rock, about 18 miles southwest of Lillooet, B.C.

Mr. Thos. B. A. Price, care of Lovell and Company, Boston, Mass.—Gold, in quartz, Gold Lake district, Big Rice Lake district, Man.

Mr. W. F. Robertson, Victoria, B.C.—An intimate mixture of bornite and galena, near Pacific, B.C.

Mr. W. G. Rutherford, Bute Court, Torquay, Devon, England, per the Right Honourable Sir Robert Borden, G.C.M.G.—19 specimens of beekite from Roundham point, near Torquay, Devon; chalcedony, Clifton, England; agate wood, River Thames, New Zealand; agate, Sartos, South America; chalcedony, Path of Condie, Loch Leven, Scotland; piece of large stalactite, 6 specimens of chalcedony, common opal, Clent Hills, Ashburton, New Zealand; 10 specimens of agate from Liebig and Company's ranch, Fraybentos, Uruguay, South America; chalcedony near Christon, Devon, England; "Moa" Gizzard stones (agates), Christchurch, New Zealand.

Mr. Shimmatsu Ichikawa of Kitashinjo-mura, Imatate-gun, Fukui-ken, Japan.—Native sulphur from the solfatara at Mt. Tateyama, Etchu province; natrolite and analcite from Maze, Echigo province; quartz twin from Kinbuzan, Kai province; naegite and cassiterite from Naegite, Ena-gun, Miro province; garnet from Ishikawa, Iwaki province; garnet from Wadatoge, Shinano province; gypsum from Yogosawa, Kai province; smithsonite from Kanegi, Etchu province; pyrrhotite crystals, Makidani mine, Kitasomayama-mura, Nanjo-gun, Echizen province; topaz crystals, Naegi, Ena-gun, Mino province; augite crystals, Mt. Yatsugadake, Kai province; augite crystals, Ichinoshinden, Ugawa-mura, Kariwa-gun, Echigo province; andesine crystals, Nishishioda-mura, Chiisagate-gun, Shinano province; pinite, Torihama, Mikata-gun, Wakasa province; zinc blende crystal and axinite crystal, Kamioka mine, Hida province; hyalite from geyser at Fukiage, Rikuzen province; amethyst, Korea; smoky quartz, Tanokamiyama, Kurifuto-gun, Omi province; rock crystal and quartz ball, Takemori, Kai province; three engraved quartz rings and quartz ball, Kinbuzan, Kai province; stibnite crystals, Ichinokama, Iyo province; scheelite crystal and quartz twin, Kinbuzan, Kai province; native gold and argentite in veinstone, Aikawa, Sado; native silver in bornite, Ikuno, Asako-gun, Tazina province; limonite after pyrite, Buseki, Chiisagata-gun, Shinano province; pyrite crystal, Yusenzi province; hematite, Ahatami, Ichigo province; rhodocrosite and barite crystals in rock crystals, Kuratani, Ishikawa-gun, Kaga province; orthoclase crystals, Tanokamiyama, Omi province; calcite crystal, Maze, Ichigo province; calcite crystal, Kamioka, Hida province; calcite, pseudomorph after Gay-Lussite, Aoki, Chiisagata-gun, Shinano province; hornblende crystal, Formosa; garnet crystals in zinc blende, Iomi, Kamiieda-mura, Imatate-gun, Echizen province; vermiculite, Matsuyahana,

Shimoikeda-mura, Imatate-gun, Echizen province; three engraved agate rings, Fukumitsu, Etchu province; 27 quartz rings, Japan.

Mr. Wm. T. Spain, per G. C. MacKenzie.—Fine specimen of molybdenite, Spain's mine (old Legree mine), lots 30, 31, con. IV, Griffith, Renfrew, Ont.

Dr. T. L. Walker, Royal Ontario Museum, Toronto, Ont.—Flexible sandstone, Punjab, India; corundum, York branch, Renfrew county, Ont.; cordierite, Garnet island, North West Territories; tungstite, Kootenay Belle mine, Salmo, B.C.; orthoclase, Okanagan lake, B.C.; native arsenic, Edward island, near Port Arthur, Ontario.

Mr. S. B. Wright, manager, Deloro Smelting and Refining Company, Deloro, Ont.—4 pieces of stellite; samples of light grey arsenic; arsenic crystals; refined arsenic; grey cobalt oxide; black cobalt oxide; finished nickel oxide; cobalt shot metal; cobalt cubes; nickel shot metal.

Collected by Officers of the Department.

Mr. E. L. Bruce.—Fine specimens showing large staurolite crystals in garnet schist from island in Crowduck bay, Wekusko lake, northern Manitoba.

Mr. D. D. Cairnes.—*From Mayo Area, Y.T.* Quartz carrying small quantities of iron pyrites together with alteration products of pyrites, melanterite, and ferric hydrate, from Blue vein, Stewart-Catto group, Dublin gulch; coarsely laminated white quartz carrying small quantities of iron pyrites with oxidation products melanterite and ferric hydrate, Olive claim, Dublin gulch; vesicular quartz with ferric hydrate and carbonate of copper, Stewart-Catto group, Dublin gulch; quartz with ferric hydrate and carbonates of copper, Blue Lead group, Dublin gulch; scheelite concentrate from head of Bum Boy gulch, tributary of Dublin gulch; placer concentrate containing cassiterite, scheelite, wolframite, and garnet, from Dublin gulch.

From Upper Stewart River District, Y.T. Manganite collected by Mr. Archie Martin.

From Near Ogilvie, Y.T. Quartz schist holding small quantities of sulphate of iron.

From Canadian Creek, Klotassin Area, Y.T. Quartz holding amphibole; quartz holding some hematite; quartz holding tourmaline; granitic rock showing small yellow patches of siliceous matter and ferric hydrate; scheelite concentrate.

From Windy Arm District, Y.T. Quartz, arsenopyrite, and galena from Venus Extension claim; quartz, arsenopyrite, realgar, and orpiment from Venus Extension claim; white quartz carrying tetrahedrite, pyrargyrite, and galena; specimen stained with blue and green carbonates of copper, from M and M claim; galena and mispickel from Venus No. 2 claim; quartz and galena from Venus claim.

From Atlin Mining District, B.C. Native arsenic from Engineer mines, Taku arm; chrompicotite from Ruby creek.

From Near Parrsboro, N.S. Crystalline quartz carrying native copper with blue and green carbonates of copper; acadialite or chabazite; acadialite, heulandite; amygdaloidal trap carrying amygdaloids of stilbite and heulandite; sandstone carrying manganese.

From Winding Hill, N.B. Quartzite and quartz carrying small quantities of crystalline galena.

Mr. Charles Camsell.—Hubnerite in quartz, Cathedral mountain, Ashnola river, B.C.; topaz, Burnthill brook, York county, N.B.

Mr. A. O. Hayes.—Magnesite, one mile east of Orangedale, Inverness county, N.S.

Mr. G. C. MacKenzie.—Molybdenite, Alice arm, Observatory inlet, B.C.; molybdenite, Quyon, Que.; molybdenite, Olalla, B.C.

Mr. A. McLean.—Polished septarian concretion from Estevan, Saskatchewan.

Mr. S. E. Slipper.—Sample of petroleum from the Moose Mountain Oil Company's well on the east ½ of sec. 34, tp. 23, range 5, W. 5th mer. Alberta; sample petroleum from the Lineham well, Pincher Creek, Alberta; sample of petroleum from the Alberta Oil Company's well, No. 1, southwest corner of sec. 18, tp. 20, range 2, W. 5th mer., Alberta; sample of petroleum from the Calgary Petroleum Products Company's well No. 1, on sec. 6, tp. 20, range 2, W. 5th mer., Alberta; samples of petroleum from the Alberta Petroleum Company's well No. 2 (Herron Elder well) on sec. 1, tp. 20, range 3, W. 5th mer., Alberta; sample of petroleum from the Acme Oil Company's well, sec. 16, tp. 19, range 2, W. 5th mer., Alberta; sample of petroleum from the North Western Pacific well No. 1, on sec. 24, tp. 20, range 3, W. 5th mer., Alberta.

Mr. A. W. G. Wilson.—Calamine and lusitanite from Hudson Bay mine, Salmo, B.C.; brownish black crystalline sphalerite associated with a little pyrite, Lucky Jim mine, Zincton, Slocan mining division, B.C.

Mr. W. J. Wright.—Oxide of manganese in shell cavities, Manganese mine, Markhamville, N.B.

Purchases.

Mr. J. D. Andas, Princeton, B.C.—Four platinum nuggets, from a tributary of the Similkameen river, 14 miles from Princeton, B.C.

Mr. A. L. Bailey, Ottawa, Ont.—Cobalt silver ore (Float specimen).

Mr. John Hopp, Vancouver, B.C.—Series of gold crystals from the John Hopp mines, near Barkerville, Cariboo, B.C.

Mr. W. Mobbs (per Dr. W. F. Ferrier).—1 gold nugget from three-fourths mile up McGillivray creek from Anderson lake, Lillooet mining division, B.C.

Field Work.

Mr. Eugene Poitevin spent a portion of the summer in collecting mineral specimens at a number of localities in the provinces of Quebec, New Brunswick, and Nova Scotia. Four weeks between June 17 and July 17, were spent in the examination of mines in the neighbourhood of Black Lake and Thetford, Megantic county, Quebec, and during this time Mr. Poitevin secured a number of interesting specimens to add to the large series already obtained from there. These include hydromagnesite, grossularite, fibrous diopside crystals, zeolites, and albite and some as yet undetermined minerals. These will be described in a bulletin which is now in course of preparation by Professor R. P. D. Graham of McGill university and Mr. Poitevin, on the minerals of these areas.

Mr. Poitevin next spent a few days collecting at the zinc mines near Notre Dame des Anges in Portneuf county. Amongst other interesting specimens secured at this locality were some stout crystals of rutile. It has not been determined as yet whether or not there is any abundance of the mineral at this locality, but it would seem to be a matter worthy of investigation.

Following this Mr. Poitevin devoted his attention until August 15 to a study of the mineral occurrences at the West Gore antimony mine in Nova Scotia and at the Lake George antimony mine in New Brunswick. It has not been possible, as yet, to make a detailed study of the minerals collected at these places.

Exhibition Work.

Acting on instructions from the Deputy Minister of Mines a display of Canadian economic minerals was arranged for the Central Canada exhibition held in Ottawa in September. An area of 400 square feet was allotted for the purpose in Fine Arts Building. The erection of the necessary shelving and stands was carried out under the direction of D. A. Esdale, while the placing of the exhibits was entrusted to A. T. McKinnon. The display embraced specimens of silver, copper, lead, zinc, tungsten, and molybdenum ores, raw and manufactured asbestos, gypsum, graphite, mica, etc. An interesting item in this display was a collection of manufactured products donated by the Deloro Smelting and Refining Company, Deloro, Ont.. including various forms of cobalt and nickel and arsenious acid and the new chromium-cobalt-tungsten high speed alloy called stellite, which is now being produced at the Deloro works.

The Exposition of Chemical Industries in the Grand Central Palace, New York, September 25 to 30, was visited by Mr. R. G. McConnell, Deputy Minister of Mines, accompanied by the writer, on September 28 and 29. The exposition occupied the ground floor and the wide gallery of the Grand Central Palace and illustrated well the remarkable progress made in chemical industries in America during recent years, more particularly since the outbreak of the present European war. Amongst the manufacturing industries which have recently undergone very rapid development in the United States are those of the coal tar derivatives and of glass and porcelain. Among the coal tar derivatives, dyes occupy a very prominent position and a great measure of success has been attained in their production; other manufactures which have received a great impetus are the various artificial abrasives and explosives; these industries were represented by extensive and carefully planned displays.

The exposition was open to the public in the afternoons only and was attended by from fourteen thousand to sixteen thousand persons daily It would seem that something of the same kind carried on in Canada could not fail to benefit Canadian chemical manufactures.

Educational Collections.

During the year just closed the number of applications for educational collections of minerals, which have been received from school authorities, has increased over 60 per cent over those received in 1915, a circumstance which may be taken as evidence of the increasing popularity of these collections amongst the educational institutions of the country. Collections have been distributed as follows:

Province	Standard	Grade two	Miscellaneous	Mineral chips	Prospector's
Yukon	1	..	....	..	..
British Columbia	1	..	2–155 sps.	..	2
Alberta	3	6	......	..	1
Saskatchewan	4	16	....	..	..
Manitoba	5	2	....	..	..
Ontario	12	5	39–1,340 sps.	2	..
Quebec	6	10	6–32 sps.	..	..
New Brunswick	1	..	....	..	..
Nova Scotia	6	2	1–9 sps.	..	..
P. E. Island	2	..	....	..	..
Foreign	..	..	12–169 sps.	..	..
	41	41	60–1,705 sps.	2	3

As outlined in the Summary Report for 1915 some changes have been in contemplation in regard to the arrangement of these collections. Owing, however, to the disturbed conditions in the Museum building and pressure of other work it has not been found practicable to give this matter the required attention.

A paper on the use of educational collections in Canadian schools was read by the writer before the Ontario High School Teachers association in Toronto in April. In the discussion which followed many of the difficulties with which teachers are confronted in their classes in different branches of natural science were stated. A knowledge of these difficulties will be of assistance in reconstituting the mineral collections.

During the past season Mr. McKinnon spent seven weeks in the field collecting from various localities in Ontario, Quebec, New Brunswick, and Nova Scotia. In all, he has, during the season, assembled nearly seven and a half tons of material for use in the educational collections.

Special thanks are due to the following gentlemen for favours and assistance in securing the materials required:

Mr. John Wasson, Two Islands, N.S.; Mr. Albert Berry, Two Islands, N.S.; Mr. George Corbett, Five Islands, N.S.; Mr. Oscar Bennett, Parrsboro, N.S.; Hon. C. J. Osmand, Hillsborough, N.B.; Mr. F. B. Thomson, Hillsborough, N.B.; Mr. Thos. Lowther, Hillsborough, N.B.; Mr. Rupert Lewis, Hillsborough, N.B.; Mr. James Livingstone, Albert Mines, N.B.; Mr. James Robertson, Albert Mines, N.B.; Mr. John McDonald, Glencoe, N.S.; Mr. John Cherry, Perth, Ont.; and Mr. Bush Winning, Notre Dame de la Salette, Que.

Meteorites.

New Iron Meteorite.

On August 15 last the department received from Mr. F. Bradshaw, chief game guardian, Regina, Saskatchewan, some small fragments of metallic iron regarding which he desired an opinion. The fragments had been detached from a larger piece and sent to Mr. Bradshaw by Mr. William Huiras, Annaheim, Saskatchewan. The examination of the fragments left no doubt that they were of meteoric origin.

In the course of mowing operations on his farm on July 30, 1916, Mr. Huiras was attracted by an unusual sound when the guards of his mowing machine struck some hard substance lying in the grass and on examination he found this to be a mass of iron which he later forwarded to the department for inspection. Through subsequent negotiations the specimen became the property of the department and is now in the custody of the Museum.

Additional interest attaches to the specimen by reason of certain meteoric phenomena which are reported to have occurred in the neighbourhood on an afternoon about the end of January or beginning of February, 1914. These phenomena are said to have consisted of the appearance of a glowing body in the sky followed by a series of detonations and rumblings, a cloud of smoke being left in the wake of the flying body. Whether there is any direct connexion between these phenomena and the specimen under consideration may never be definitely established, but the fact that the specimen was lying loose in the grass would lead to the supposition that its fall may have been arrested by snow or ice rather than by immediate contact with the earth, in which case it probably would have become buried.

This iron is a peltoid weighing 11·84 kilogrammes and will be the subject of further investigation and description.

Australian Meteorites.

Specimens of the following Australian meteorites have been added to the Museum collections during the year: Hermitage Plains—Hermitage plains, 20 miles southeast of Canbelego, N.S.W. Molong—E. Farrell's selection, Portion 218, Pa. Molong, Ashburnham, N.S.W. Gilgoin—Gilgoin Station, 40 miles southeast of Brewarrina, N.S.W. Mount Dyrring—Mount Dyrring, 8 miles north of Bridgman, Singleton district, N.S.W.

BORINGS DIVISION.

(*Elfric Drew Ingall.*)

The work of the division was carried on during 1916 along the general lines adopted in previous years. It is the duty of the borings division to collect all obtainable data relating to borings made throughout Canada and to utilize the information derived from the study of this material for the more intelligent prosecution of subsequent boring operations.

Whilst the borings division pursues a continuous policy of inquiry regarding boring operations for the whole country, in some districts the collection of data can best be carried on by the geologists investigating those fields, since they are able to keep in touch with the operations of drillers and to induce them to furnish samples and records. In this way systematic collecting of records in Alberta was again carried on by D. B. Dowling and S. E. Slipper. Similarly during the investigation of the Ordovician formations of the peninsula of Ontario, M. Y. Williams collected a large number of boring records. The division was able to co-operate with Mr. Williams by utilizing the collections of drillings samples filed in the office. The interpretation of these and other sets of samples by means of microscopic, chemical, and other tests has resulted in information of great practical use to investigating geologists and to operating drillers.

Since the inauguration of the borings division of the Geological Survey in 1908, many logs of wells have been collected, and thousands of samples have been sent in by drillers from borings made in various parts of Canada. Besides those collected during this period there are packed away in the offices of the division a great many sets illustrative of borings made in past years. Special experience is required in utilizing this material for the elucidation of economic and geological problems in order to avoid errors in interpretation. Where a number of complete sets of samples are available for any district, taken at intervals of 10 feet or thereabouts, many of these possible sources of error can be avoided.

In attempting to utilize the drillers logs of borings, for the purpose of geological interpretation in any district, the need of re-interpretation and corroboration of such records by a study of sets of drillings samples becomes very evident.

To the driller, primarily interested in the progress of the boring, the correct and detailed description of the strata passed through seems to be of secondary importance. He will for this reason overlook features vital to the proper understanding of the stratigraphical succession. Furthermore the terminology used in these logs is often found to be incorrect having been based upon experience gained in other districts where the geological succession is entirely different from that found where the boring is being made.

In order then to make use of the material accumulated, samples from groups of wells must be set out and studied collectively and in detail. Although such work is necessarily tedious and difficult there should result a considerable addition to our knowledge of the succession, thickness, and attitude of the various strata where their extension in depth is carefully studied. A better understanding of

the lithological variations of any horizon in its underground extension over large areas is thus obtained. It was found possible to work out in this way a limited number of drillings sets towards the end of the year for the use of Mr. Williams in his study of the Ordovician strata of Ontario.

Some useful data may be obtained from a microscopic search of drillings for fossils. Most of the samples sent in are in the form of broken material from holes put down by the churn drill. In these it is generally possible to find unbroken only the smaller forms such as ostracods, foraminifera, fragments of bryozoa, etc.; but in some cases, larger fragments are obtained containing fossils which enable the geological horizon of the beds to be definitely fixed, as was the case with the Jurassic fauna recognized in material obtained some years ago by the borings division from a deep-well at Moosejaw, Sask.

Where by good fortune samples are obtained from borings put down with some form of core drill, investigations along the lines set forth above are greatly facilitated. In the case of the cores from the deep boring at Taber, Alberta, now in the collections of the division, not only are the lithological peculiarities of the strata well illustrated but a number of well preserved fossil remains are available for study and comparison and for use as horizon markers.

An interesting feature in the examination of borings from southwestern Ontario, was the recognition of an arenaceous horizon, possibly the Sylvania, at a depth of about 366 feet in the borings received from Jas. Peat & Sons, contracting drillers of Petrolia, Ont., from a boring near Wingham in Huron county, Ontario. A somewhat similar bed had been previously recognized at a depth of 300 feet in drillings from a deep boring in Middlesex county, Ontario. Whilst in the latter case the probable æolian character of the sand grains was well demonstrated, in the former this character was not apparent, and the siliceous material was more sintery in character.

Thanks to the courtesy of the Dominion Natural Gas Company of the Niagara peninsula a number of logs of wells have been obtained and it is hoped that a still closer co-operation can be maintained with this company during the coming year.

The data already accumulated by the division, as well as the geological information obtainable from the literature on the subject has again, during 1916, been utilized on behalf of boring operators active or prospective. When boring operations are contemplated and during the actual putting down of wells it is of the greatest practical importance that the geological conditions of the district should be kept in mind and it has been found possible to give such assistance to inquirers in a great number of instances.

For the elucidation of the practical problems involved in the search for gas, oil, or water by boring, not only are geological data necessary, but knowledge and experience are required for the effective application of these data to the problems involved; and in this the Geological Survey is able to be of service. As in former years a considerable part of the time of the small staff of the borings division has been spent in replying to numerous inquiries either written or personal. Amongst trained mining engineers and geologists it is recognized that a thorough study of the geology of any district is an absolute necessity where search for gas and oil by boring is contemplated; but, unfortunately, the working driller and the public generally do not appreciate this necessity to the same extent. It is also little understood that the collection of boring records and sets of samples and their subsequent study is of the greatest importance if their accumulative lessons are to be used in guiding future boring activities. Whilst a fair measure of co-operation between the drillers and the division has resulted from the efforts of the past five years much remains yet to be accomplished in this direction. The assistance which it has already been possible to give will doubtless help in the popularization of the work and the co-operation of working drillers will be increasingly ensured.

As might be expected, boring operations have shown the effects of war conditions and have not been as vigorously prosecuted as in previous years.

In Nova Scotia the only particulars in regard to boring operations which have become available are those given in the recent report of the Department of Public Works and Mines for the province relating to operations carried on in 1915. Of the six government core-drills only one was in operation during the year mentioned. The hole put down was at Thorburn in No. 4 level, west side, 567 feet from the main slope on the Vale seam and was undertaken for the Acadia Coal Company. The log is given in the report. The cost of the bore is given as follows:

Labour	$295.50
Management	306.00
Coal	670.56
Light oil, waste	12.58
Carbons	70.39
Housing	34.73
Total	$1,389.76 or $1.77 per foot.

The rocks passed through were sandstones and shales with some coal seams, the first mentioned constituting about one-third of the whole.

No returns were received from New Brunswick but at the request of the New Brunswick Gas, Oil Fields Limited, a number of sample bags were sent them. Sets of samples may, therefore, be expected from them later as their policy in the past in co-operating with the division has been to hold them in reserve until the completion of the wells, then to return them all together.

In Quebec very little boring was carried on. The Canadian Natural Gas Company continuing their operations in Ste. Hyacinthe county completed their No. 4 well in St. Rose range to a stated depth of 3,000 feet. Samples taken to a depth of 2,380 feet have been received. In St. Amable range the company began and completed their No. 5 well to a depth of 2,500 feet. The National Gas Company, with head offices at Ottawa, started a new well in the St. André range which was bored to a depth of 1,826 feet. Both these wells were bored by Mr. Edward Coté, drilling contractor of Montreal.

This group of seven wells is confined to an area of about 16 square miles, whose centre is about 6 miles north of the city of Ste. Hyacinthe. With the exception of well No. 4 of the Canadian Natural Gas Company all these borings traversed the red sandy shales for about 1,000 feet in the upper part of the borings. These represent the highest strata of the series and are classed as of Medina age on the geological map of the district. They are considered as corresponding with the Queenston shales of the succession as worked out in the peninsula of Ontario. They are shown on the map as occupying several synclinal troughs which lie in a northeasterly direction from the group of wells in question. Taking into account the general northeasterly trend of these folds, the majority of the borings under consideration would seem to be in the southwesterly extension of the fold lying west of Yamaska river and not far from the great St. Lawrence-Champlain fault.

The sharp bend in the course of Yamaska river brings to light evidence of an anticlinal arch in the strata near the village of St. Hugues and assuming a continuation of this arch southwesterly along the general strike of the strata, it should be found between the group of borings in the synclinal and the Yamaska river. With a view to testing this point in regard to the probable structure as expressed by the Survey officials the company bored their No. 3 well. The fact that no red beds appeared in the series of samples sent in by the driller showed that they were on some portion of the expected anticline. Although no economic results were obtained one boring cannot, of course, be taken as conclusively testing the questions involved.

It is to be regretted that the structure, which it is necessary to ascertain for the correct placing of deep wells, could not have been worked out as advised by first sinking a number of shallower holes with a light portable rig. Then, when a suitable site was found the necessity for piercing a thousand feet or more of the upper strata could be avoided and it might be found possible at a reasonable depth to reach the Collingwood horizon between the Richmond and Lorraine formations and the Trenton limestone. As the Collingwood horizon has been found to be gas-bearing in the westward extension of these formations in the Ottawa district, it is a fair assumption that profitable results might be obtained. This point, together with the geological evidence available for the district, has been discussed with the operators on a number of occasions and recently also with Prof. C. Johnson of the University of Pennsylvania when on his way to make an expert examination of the field. Should this gentleman's reports to his clients confirm the advice already given the operators a renewal of boring tests of a more systematic kind may be hoped for.

In Ontario very little was done in the eastern portion of the province. Boring to test the known gas-bearing Collingwood formation at the top of the Trenton was suspended except for the commencement of a boring near Bourget, 25 miles east of Ottawa, with a heavy standard rig. This hole was put down it is said to about 600 feet, but operations were then suspended although the operators announced their intention of going to a depth of 1,800 feet. No samples from the upper part of this hole were sent in, but from the known geological succession in that vicinity it must probably have started in the top of the Trenton strata where they emerge with a very flat southerly dip from below the Collingwood or gas-bearing horizon. Judging from the evidence available to date at a depth of 1,800 feet a boring at this point would pass through all the sedimentaries and enter the underlying Archæan granites, gneisses, etc., a considerable distance.

From the evidence of old wells and of a number recently put down to the rock surface by the drive pipe method, evidences of natural gas are widespread through an extended district. There is need, however, of systematic preliminary exploration by rapid and cheap boring with portable rigs rather than by a few expensive borings with the heavier and more cumbersome apparatus. In fact the geological data so far available lead to the belief that, as far as the probable extension in depth of the gas-bearing portions of the Collingwood horizon is concerned, the depths of holes required would probably be nowhere more than half that contemplated by the operators.

The chemical character of the natural gas occurring in this district is illustrated by the following analysis.

Analysis of Gas from Plantagenet Township.

Solubility in Alcohol. No portion of the gas dissolved in alcohol, showing that the sample is a dry gas.
Composition. Methane...........85·0 per cent.
Nitrogen...........15·0 " "
Specific Gravity. By effusion apparatus, 0·610 (by calculation, 0·620).
Analyst, Edgar Stansfield, Mines Branch.
Collected by E. D. Ingall.

In western Ontario negotiations were entered into with the Dominion Natural Gas Company looking to the co-operation of the borings division with their corps of field inspectors. Correspondence with Mr. D. W. Williams, geologist for the company, elicited very generous offers of assistance, and during the latter part of the year results were obtained in the form of logs and sets of samples from some wells.

Information and assistance were given by the following: Henry Fuller, Dunnville, Ont.; Roy Lindsay, Dunnville, Ont.; Joseph McKee, Chatham, Ont.; C. C. Roberts, St. Thomas, Ont.; Harrison Stringer, Simcoe, Ont., and Francis D. Moore, Buffalo, N.Y.

Through the assistance of J. Stansfield who was making geological investigations in the vicinity of London during the summer, the borings division was put in touch with a number of drillers and a number of logs of wells were obtained. M. Y. Williams collected nineteen logs from points in western Ontario during the summer of 1916.

Samples and logs of two wells were obtained in the Haileybury district from Mr. G. H. King, driller, by G. S. Hume. These will throw some interesting light on the thickness and character of the interesting outlier of the Palæozoic formations found there.

The data above mentioned as contributed by the field geologists of the staff will be found in the summary reports of these officials elsewhere in this volume along with the other geological data resulting from their investigations.

From Manitoba records and samples from a few shallow wells were received from drillers. Under an arrangement made by the Geological Survey with the Manitoba government, copies made of the logs of some 1,696 shallow wells are now added to the files of the Division. These should throw considerable light on the important question of the occurrence of water in the superficial deposits.

Deep boring operations were not very active in Saskatchewan during 1916 and the division was, therefore, not in receipt of many records from that province.

In Alberta, as previously stated, the progress of boring operations is being watched for the Survey by S. E. Slipper, and the boring records and samples have for some years been kept at the headquarters office for that work in Calgary. These will eventually be brought to Ottawa and incorporated in the general records of the borings division and become available for general reference and study. Borings data for Alberta collected during 1916 will be found in the summary reports of D. B. Dowling and S. E. Slipper elsewhere in this volume. A number of records received from the same source have been added to the files.

A. Gothenquist, operating for the Youghren Drilling Company, very kindly sent in a number of logs of shallow wells from the southern part of the province, as well as some interesting analyses of water obtained.

As far as could be ascertained very little deep boring was done in British Columbia. No further information was sent in regarding the deep bores in the Fraser River estuarine formations at Pitt Meadows and Port Haney.

In the various provinces the testing of mineral deposits by means of the diamond drill is often reported but these being of value only to the operators and yielding data of no general public utility no effort is made to get reports regarding them.

During the year the staff of the division has consisted of E. D. Ingall, in charge, with J. A. Robert as assistant chief; M. Mahoney was attached to the staff in March and has rendered assistance in the office routine and in handling the sets of samples received. In the early part of the year the moving of the material from the offices in the Victoria Museum and its rearrangement in new quarters was the cause of considerable interference with the prosecution of the work.

CANADIAN ARCTIC EXPEDITION 1916.

(*R. M. Anderson.*)

Written at Bernard Harbour, Dolphin and Union Strait, January 13, 1916.

As stated in my last report, August 12, 1915, the party remaining at cape Barrow consisted of four men: K. G. Chipman, J. R. Cox, J. J. O'Neill, and myself. By previous agreement with Mr. Wilkins, the *North Star* returned westward, bound to Herschell island, and ultimately to Banks island. This, of course, was a handicap to our summer work as originally planned, as we had to lie over a good many days on account of stormy weather and high winds when we could not use the small boats, and when we might have gone ahead or anchored in more favourable places with the *North Star*. With the small boats we had to find a very small and very well protected harbour for each night's camp. It also prevented us from getting back to the station before the freeze-up, as the almost continuous heavy weather late in the autumn prevented us from travelling a large part of the time with the small boats. We had to find a sheltered harbour every night for the launch, and unload and haul up the 30-foot umiak every time we wanted to camp. The Evinrude motor on the umiak did good service in the early part of the season, and the two boats were able to work to some extent independently, by having one boat make more prolonged stops for geological work at the most interesting points, while the launch could keep running more or less continuously on the coast traverse. In the latter part of August, the Evinrude motor on the umiak gave out completely, and, as we were not prepared to re-babbitt the bearings, we had to lay the umiak up near Kater point, as it reduced the speed of the launch about a mile per hour to tow the umiak. The failure of the Evinrude made it necessary for Mr. Chipman to stay at Kater Point camp for about three weeks and unavoidably cut down the topographic field work considerably. On the return of the launch to Kater point, the umiak was towed back to the Tree River base camp (67° 46′ north, 111° 59′ west).

We carried on a complete topographic survey of the coast from cape Barrow around Moore bay and Arctic sound, up Hood river to the first cascade, and well down into Bathurst inlet, while Mr. O'Neill made geological investigations at all points along the coast, and at many points for some distance inland, wherever the geological conditions promised to throw light on the occurrence and relations of the copper-bearing rocks in particular. As the season was getting late, we felt impelled to turn back from Barry island, Bathurst inlet, on September 8, 1915, without going to the bottom or the east side of Bathurst inlet. It was thought that the survey from Kent peninsula westward could be completed in the coming spring by sledge. After a long delay, eight days storm-bound, with heavy snowfall and freezing weather, in a little harbour near Kater point, we got back to the mouth of Tree river, Port Epworth, on September 30. As the freeze-up of Coronation gulf was impending, we decided to stop at Tree river and return to the winter base at Bernard harbour by sled. Stormy weather followed for four days and the young ice was pretty thick on October 6.

We had our three best dogs with us on the boats during the summer, for use in packing inland, and for tracking boats if necessary. Seven dogs and two sleds had been left in charge of some Eskimos at the summer fishing camp at the first rapids on Tree river when Cox and O'Neill left Tree river on July 30. We had shot numbers of Arctic hares, some seals, one large Barren Ground bear, and three caribou in August and September, and had all the fresh meat we could use, as well as fresh fish quite frequently, when we had time to set a net in the summer.

The abundance of meat and fish naturally cut down the consumption of the travel rations with which we were well provided. Our Eskimos at Tree river had killed a number of caribou there about the time we arrived, and we had plenty of fresh meat all the autumn. About five hundred pounds of dried fish were put up at Port Epworth in the summer and cached there by Cox and O'Neill. The four members of our party, Chipman, Cox, O'Neill, and myself, accompanied by one Eskimo sled, started from Tree river on October 27, as soon as we considered the sea ice strong enough for travel, and reached the station at Bernard harbour on November 9, 1915. Several cases of my zoological specimens and Mr. O'Neill's geological specimens were cached at Port Epworth to be hauled home in the winter.

The only natives seen east of Tree river during the summer were three seen at a distance near Kater point. Eskimo caches were seen on rocks at Cheere islands and on point Wollaston, Banks peninsula (in Bathurst inlet), and we were informed by the Tree River Eskimos that there were four families, with three tents, spending the summer fishing at the rapids near the mouth of Annielik river, the most western of the rivers flowing into Gray bay. Sixteen Eskimos, 6 men, 6 women, and 4 children, comprised the group which spent the summer fishing at the rapids about 5 miles from the mouth of Tree river.

Cox and O'Neill made investigations on some of the islands of the Duke of York archipelago, Coronation gulf, and in the vicinity of Port Epworth in the early summer and packed up the Kogluktualuk (Tree river) 25 or 30 miles in July. The Kogluktualuk is a fairly large river with several waterfalls and many rapids. One branch of it comes from the west, heading near the east side of Coppermine river, and is said by the Eskimos to have spruce trees near its source.

D. Jenness, ethnologist of the southern party, arrived at the station on November 8, 1915, after having been with the Eskimos on Victoria island since April 13, 1915. They had spent most of the summer in the Colville hills, in southern Victoria island, and did not go to Prince Albert sound as had been anticipated. A few Prince Albert Sound natives came down to visit them in the spring, however. Mr. Jenness did not suffer from lack of food during the summer, obtaining fish plentifully from the lakes, and caribou in reasonable numbers (but no large herds) all summer and autumn. The principal discomfort he experienced was being without fuel much of the time, as many districts visited did not afford a sufficient quantity even of dwarf willow or heather. This obliged him to eat the meat and fish in a raw state oftener than was desirable.

The Barren Ground caribou began to migrate south across Dolphin and Union strait shortly after our return from the east, and were coming in fairly large numbers by November 15. About forty were taken before the end of the month (including about ten brought by Mr. Jenness from the south coast of Victoria island), so we have had a plentiful supply of fresh meat for the winter. Fresh fish were also taken in numbers up to the middle of December in nets set under the ice of the lakes near the station.

The *Alaska* arrived at Bernard harbour on September 5, 1915, after going from Baillie island to Herschell island for the mail and supplies. After discharging cargo here, the *Alaska* went back west to Stapylton bay to look for driftwood, as the amount of coal brought in was smaller than had been expected. Some coal was taken on at Herschell island, and the remainder of the expedition's coal at Baillie island was taken to outfit the *Polar Bear* for her northern voyage. Captain Sweeney of the *Alaska* had cached his surplus coal, coal-oil, distillate, and some miscellaneous goods, including a large case of tinware, etc., at Baillie island when he went west, and in his absence the *North Star* came in to Baillie island from the east, and taking practically everything at Baillie island, sailed directly for Banks island. On this account the *Alaska* had to come in here with

considerably less coal and three drums of distillate less than was expected. Wood is scarce in this locality. Not very much driftwood comes east of cape Bexley, and as the *Teddy Bear* wintered in this harbour once before (in 1912-1913), and the southern party had been here during the last year, most of the wood had been picked up, and we have had to keep three sleds busy hauling small sticks most of the autumn in good weather, mostly from Cockburn point, about 10 or 15 miles west of here. As to distillate, we have just about enough to take us to Herschell island.

Mr. Frits Johansen, biologist, accompanied the *Alaska* on the trip west to Stapylton bay. He got some valuable deep soundings and dredgings in Dolphin and Union strait, down to a depth of 50 fathoms, and obtained a quantity of specimens from greater depths than he had been able to reach before. Mr. Johansen made continued studies throughout the summer of the freshwater life of the ponds and lakes in the vicinity of the station, and made fairly complete collections of the flora and insect life. In the autumn he completed a series of soundings of the outer and inner harbours here, through the young ice, in continuation of work begun in the autumn of 1914. The lines were run between islands and points of the mainland, with the soundings at paced distances, from 30 to 250 feet apart. The result was the finding of very interesting hydrographic conditions, the maximum depth being 12 fathoms. This information is of great value in connexion with his other marine investigations and with the topographical map of the harbour. Mr. Johansen also did some other hydrographic work, taking soundings in the neighbouring freshwater lakes, working through the young ice in the autumn.

Corporal W. V. Bruce, Royal North West Mounted Police, came in from Herschell island in the autumn on the *Alaska*, to conduct investigations in regard to the disappearance of two Roman Catholic priests from the mission at Fort Norman, who disappeared in the Great Bear Lake region more than a year ago, and are supposed to have been murdered by Indians or Eskimos. He made one trip in October and November to the large Eskimo village at the mouth of Coppermine river, in company with one of our Eskimo interpreters, and another trip to the village at the Liston and Sutton islands in company with Mr. Jenness, our ethnologist. The expedition, by the assistance of interpreters and otherwise, has endeavoured to assist him as much as possible in the prosecution of his investigations among the Eskimos.

Captain Daniel Sweeney, of the *Alaska*, with two Eskimos, left here November 5, crossed to the Victoria Island side, and thence across Coronation gulf to Tree river to look for our eastern survey party; but, learning from the Eskimos there that we had already gone west, he returned to Bernard harbour on November 22.

Rev. H. Girling, Church of England missionary, made an attempt to come in to this district last summer with the little mission power schooner *Atkoon* of Collingwood, from Mackenzie river, but was unable to get farther east than Clifton point on Amundsen gulf, where he went into winter quarters (69° 13′ north, 118° 40′ west). He visited the station at Bernard harbour in the autumn and expects to spend some time this winter doing missionary work at the large Eskimo winter village at Ukullit (Liston and Sutton islands). The gasoline schooner *El Sueno* came in here in September, to land some additional supplies for the expedition, and went west again, intending to winter at Pierce point, trapping and trading. The Hudson's Bay Company put in a new station last summer (1915) at Herschell island, in charge of Mr. Harding, and a station at Baillie island (cape Bathurst) in charge of Mr. Larson.

Mr. Daniel Wallace Blue, chief engineer of the *Alaska*, died at Baillie island, on May 2, 1915, after an illness of ten days. He had been troubled a little in the latter part of the winter by what Captain Sweeney thought was incipient scurvy.

The only noticeable symptom was that when his legs were punched with a finger, the indentations remained for a short time. No other scorbutic symptoms appeared. Captain Sweeney and some of the natives at Baillie island had the symptoms, as did also a trapper named Fred Jacobsen, who wintered around Liverpool bay, and Mr. Arey and Mr. McIntyre on the *Argo* at Darnley bay. Mr. Jacobsen came over to Baillie island in the spring and Mr. Blue accompanied him on a sled trip along the coast after ptarmigan. They were all improving in condition as spring approached, and in fact had never been seriously inconvenienced all winter. A few days later, Mr. Jacobsen brought Mr. Blue back on the sled, suffering from a severe congestion of the lungs. The pneumonic symptoms grew worse and Mr. Blue died on May 2. Mr. Blue was buried on cape Bathurst. Mr. Blue was one of the original crew shipped on the *Alaska* at Nome. He was born in Scotland about thirty years ago, and learned the engineering trade in Glasgow. He had lived in Alaska since 1906, and had followed the placer mining industry (both prospecting and operating) on Copper river, and at Tanana, Nome, and Kobuk, Alaska. There has been no illness among the members of the expedition who have been here the past year, except a slight illness of Mr. Jenness, while he was spending the summer on Victoria island, and all members of the southern party are now enjoying robust health.

D. Jenness, ethnologist, has been spending much of his time this winter among the Eskimos who are living in a snow-house village in the middle of Dolphin and Union strait, about 16 miles north of here. He is intending to take a trip to Prince Albert sound in the latter part of the winter, and after that possibly make a trip to Kent peninsula in the spring. Only three or four Eskimo families were around here in the late summer and early autumn, but about the middle of November they began to come up from the Coppermine River region, and most of them stayed here for three weeks or more in a snow-house village on the beach. They were living principally on caribou meat, while their women were engaged in making new caribou-skin garments for the winter. In the early part of December, when their new clothing was completed, and their meat and dried fish began to run short, they moved out to the vicinity of the islands in the strait to live on seals during the rest of the winter. While the Eskimos were here Mr. Jenness greatly enlarged his collection of ethnological material, getting good duplicates of a great many things. Considerable skin clothing was also purchased from them, by barter, for the use of members of the expedition.

During the year 1915, the survey of the coast-line was completed by Chipman and O'Neill from the west side of Darnley bay to Stapylton bay, and from thence by Mr. Cox as far east as the mouth of Rae river, near the southwest end of Coronation gulf. Mr. Cox carried the survey of Rae river up about 75 miles to the point where Rae river is formed by the junction of two creeks. From that point he made an overland traverse to Stapylton bay. There is still a gap in the coast survey, from the mouth of Rae river to Tree river (Port Epworth), Coronation gulf. Cox and O'Neill worked for a short distance around Port Epworth last summer and some distance inland from that point, and made a boat journey along the coast from Port Epworth to cape Barrow, Coronation gulf. From cape Barrow, a detailed survey was completed east around the coast, including Moore bay and Arctic sound, some distance into Bathurst inlet. We did not go to the bottom of Bathurst inlet, as the season was getting late, and we agreed with Mr. O'Neill, that we could do more valuable work in the limited time at our disposal, by exploring Barry island and other unexplored islands in that vicinity, where the most promising copper indications were found, while the rock formations were free from snow and ice, and by leaving the remaining details of the coast-line survey to be finished by a sledge party next spring.

Some rectification of the charts in the Bathurst Inlet region will result from our summer's survey, as Sir John Franklin's original survey in 1823 was made in the course of a hurried canoe voyage, and the coast-line is extremely cut up by long, narrow fiords, peninsulas, and islands, so that it is very difficult and slow work to follow the shore closely, particularly in the Goulburn Island region, or rather the series of long peninsulas east of Banks peninsula. Chipman and Cox since their return to the station have been engaged in computing positions for the plotting of maps of the surveys made last spring and summer.

The geological formation of this region is rather varied and complicated, but J. J. O'Neill gained much valuable information in tracing the contact of the basalts with the sandstones, shales, dolomite, quartzite, and granite in different places. Specimens from the geological formations were collected at all points of interest. Mr. O'Neill summarizes his work on the copper-bearing rocks, the principal subject of his investigations:

"On the whole, the results are very encouraging, for while the previously known deposits have not yet been examined, two large areas, each of several square miles in extent, were discovered, in which the native copper is widely distributed. It is proposed, during the spring of 1916, to investigate the deposits reported by Hanbury on Barry island, Lewes and Chapman islands, etc., and to investigate several uncharted islands."

Specimens of mammals and birds were collected around Bernard harbour in the spring and summer, and Mr. Jenness brought back a few zoological specimens from Victoria island. In the late summer I collected specimens at various points east to Bathurst inlet. A good series of Barren Ground caribou was collected here during the autumn migration south from Victoria island. Some caribou specimens were obtained during the spring migration, some young fawns in June, and three good summer specimens while we were in the eastern region. Of the larger mammals, our collections now embrace good series of Polar Bear, Barren Ground Bear, Barren Ground Caribou, Barren Ground Wolf, Arctic Fox, Red Fox, Wolverine, and Arctic Hare, besides many smaller species. The bird collection contains representatives of most of the species found in the region, and fairly large series of some species.

Chipman and Cox have made frequent stellar observations during the winter. Thermograph and barograph records are kept, mercurial barometer, and maximum and minimum thermometer readings taken twice daily, as well as anemometer records of the directions and force of the winds.

Tidal observations were taken here for a time in the spring of 1915, with the automatic tide-registering machine, but not very successfully, as the machine had a habit of stopping frequently, and was finally discarded.

In December, 1915, we secured tidal records continuously for one week, from December 4 to December 11; we erected a snow-house on the ice of Dolphin and Union strait, outside of the harbour islands, set up a long, graduated pole on the sea-bottom, and read the height of the tide every half hour, day and night, and at intervals of ten minutes or oftener around the periods of high and low tides. The maximum rise of tide recorded was about $2\frac{1}{2}$ feet. It is the intention to undertake another series of tidal observations in the spring of 1916.

We were unable to send up any balloons for the International Meteorological Committee in the early autumn, for the reason that the only men who were competent to set up the instruments and take the readings, were obliged to be away from the station on survey work. I wished to have Mr. Wilkins take the apparatus to Banks island, explaining how the situation was here, and that it was Mr. Stefansson's voluntary suggestion that the expedition undertake the work. The southern party's meteorologist never came to us from the *Karluk*, and we had no other man who could remain here permanently, while there were

plenty of men with the northern party; but Mr. Wilkins did not wish to take the apparatus. In November, after the survey parties returned to Bernard harbour from the field, a snow-house was erected for filling the balloons, and the observing and recording telescope was set up. However, fair, clear days have been very rare during the winter, and the balloons cannot be seen for any great distance during the short, dark days, unless the weather is extremely favourable, so that very few balloons have been sent up as yet.

In regard to your letter of November 17, 1914, enclosing instructions to all members of the Canadian Arctic Expedition connected with the Geological Survey, that the scientific work of the southern party, Canadian Arctic expedition, will be discontinued in the autumn of 1915 at the latest, so far as the Geological Survey is concerned, and that the men arrange their work so as to be conveniently situated to start to Ottawa at the close of the season by the most convenient route, I can only say that the notification was not received by any of the members of the Geological Survey staff before November, 1915 (with the exception of F. Johansen, who received his mail here on September 5, 1915), too late for any vessel to go out in the season of 1915.

I discussed the situation with the men concerned, giving my opinion that the only possible way open for any member of the party to report to Ottawa before the opening of navigation next summer, would be for a very hardy and energetic traveller on snowshoes to start out immediately, make a very difficult and arduous trip over several hundred miles of uninhabited country, reach Fort Norman on the Mackenzie river, and from there to push ahead energetically with dog-teams and guides procured from the various Hudson's Bay Company's posts; with great trouble and expense he might reach Athabaska, Alberta, by April, 1916. The only alternative route would be along the Arctic coast to Herschell island or Fort McPherson. If Fort McPherson were reached before the Dawson patrol left there it might be possible to "mush" across to Dawson with them and get out some time in the spring. None of the men felt that the situation demanded that they should undertake a winter journey of such length and tediousness, particularly as the whole of the winter would necessarily be lost in travel. Some men, of course, would have to stay here to bring out the rest of the outfit, specimens, and records. Such being the case, it was decided that the only feasible course open was to sail out from here at the earliest possible opportunity in the summer of 1916, accomplishing whatever scientific work we can do for the good of the expedition in the meantime. Nothing but absolutely insurmountable ice conditions will prevent the *Alaska* from leaving here without delay and reaching an ice-free port next summer. All the members of the expedition will be ready to go, and it is hoped that we shall have succeeded in clearing up a great part of the work which we have planned to do. As to the other vessels, of the northern party of the expedition, Mr. Stefansson has now taken charge of them, and with three vessels, and possibly four, at his disposal, should be able to bring his party out.

Written at Ottawa, December 15, 1916.

My last report was written at Bernard harbour on January 13, 1916, and in brief form brought the record of the southern party up to that date.

January and February, 1916, were spent by the geological and topographical men mostly in working up their field notes and preparing for the spring work. Mr. Jenness spent the greater part of the winter at the large Eskimo sealing village near the Okullit islands (Liston and Sutton islands) pursuing his ethnological studies. I made a trip to the first timber on the Coppermine river with some of the hunters in January and February, and brought back a few specimens

and a quantity of caribou meat to replenish the house supply. Caribou were found to be fairly plentiful down to the coast near the mouth of Coppermine river, and we also saw one small herd south of cape Lambert. The natives in this region spend the winter sealing on the ice, and at the present time do not molest the caribou from November until April.

At the outset of this trip, in January, I sent two of the Coronation Gulf natives, named Mupfa and Kohoktak, in the employ of the expedition, to haul by sledge a quantity of provisions from the station at Bernard harbour to Port Epworth, Coronation gulf, which was to serve as an outfitting base for Mr. Chipman's projected survey of the south side of Coronation gulf from Rae river to cape Barrow, and for the return trip of the two or three sledges which would be working in the Bathurst Inlet area until late in the spring of 1916. These two Eskimos faithfully hauled and cached the provisions as follows: oatmeal, case, 50 lbs.; flour, 1 gunny, 100 lbs.; sugar, 1 box, 50 lbs.; man pemmican, 2 cases, 96 lbs.; dog pemmican, 3 cases, 144 lbs.; dog biscuit, 100 lbs. On their return trip they brought back to Bernard harbour several boxes of specimens which had been cached at Port Epworth in the autumn. That spot was particularly favourable for making secure caches on account of the massive flat slabs of heavy shale lying loose on the island, affording ready material for making vermin-proof caches. Wolverines are surprisingly numerous on the coast and islands of this region, which is probably 75 miles from the nearest timber, and nothing edible can be left long without being molested or destroyed by them.

I returned to Bernard harbour from the Coppermine River trip on February 27, having been gone a little over a month. It had been arranged that K. G. Chipman should start on March 1 to make a survey of Croker river. This seems to be the largest river between Darnley bay and Coronation gulf, and nothing but its mouth had been put on the chart previously. I decided that I would accompany Mr. Chipman on this trip, which was of interest not only as giving an important geological section into the heart of the Barren Grounds halfway between Mr. O'Neill's reconnaissance from Darnley bay and Mr. Cox's traverse from the head of Rae river to Stapylton bay, but might also throw more light on animal distribution, particularly that of the musk-ox.

Owing to stormy weather we did not get away from Bernard harbour until March 6, and reached the mouth of Croker river on March 15. A small power schooner, the *Atkoon* of Collingwood, which had been built at Collingwood, Ontario, and sent down the Mackenzie river in 1914, had been driven up on the beach in September, 1915, about halfway between the mouth of Croker river and Clifton point. The three missionaries who had brought the vessel in, Rev. H. Girling, of the Church of England mission service, Mr. G. E. Merritt, of St. John, New Brunswick, and Mr. W. H. B. Hoare, of Ottawa, had built a small cabin of driftwood on the beach to winter in. They intended to move farther east in the summer of 1916, and establish a mission on the south side of Dolphin and Union strait, in a country inhabited by Eskimos. The present western range of the so-called Copper Eskimos extends usually to cape Bexley or South bay; west of that point is a 200-mile stretch of coast to cape Lyon, permanently uninhabited, and usually uninhabited west to cape Bathurst, about 400 miles.

Croker river has a broad delta, forming a triangle nearly equilateral, with base about 5 miles across at the coast, and apex about 5 miles inland where the river emerges from a rampart of low hills. After leaving the hills, the river follows many devious channels, through many gravelly and stony bars and islands. There were a few small domes caused by ice rising up, but no recent signs of water flowing and the river seemed to be frozen to the bottom all the way up, so far as we could observe. It is 60 to 70 yards wide where it emerges from the first rock (dolomite) cliffs about 5 miles from the coast. The cliffs a little inside

the first bend of the river are about 60 feet high; they are composed of stratified dolomite, yellowish on the surface, but greyish on freshly broken surfaces with some lighter-coloured bands, and lenses of calcite. The canyon walls on both sides became gradually higher inland, from 100 to 150 feet, vertical on both sides in most places. The river maintains a uniform width of about 60 yards, narrowing in one place to about 40 yards. Heavy snowdrifts overhung the west bank in many places (due to the prevailing winds), and there had been avalanches in places, making barrier ridges of very hard, ice-like, angular-fractured snow blocks extending most of the way, and sometimes entirely, across the river. The river continually makes very short, sharp bends, but its general course is northerly with no tributary creeks entering the lower course. At very frequent intervals the sides, walls, and brink of the canyon are castellated, or split vertically into sharp, angular, pointed pillars, spires, and minarets. One straight pillar in a bend of the river was about 40 feet high and not over 3 feet thick at the base.

About 12 miles from the mouth of the river, and nearly 8 miles up the canyon, there is a broadening of the stream where a large creek comes from the southeast, splitting to send a branch around a large, picturesque, pyramidal rock island about 300 feet high, before entering the river. This was the first place where we were able to get up out of the canyon and Mr. Chipman and I climbed to the top of the hill by cutting some niches and steps. The top of the canyon walls was found to be 310 feet above the river, by aneroid, and the top of the ridge behind, 350 feet above the level of the river. We could see considerable land on both sides of the river, rather smooth, rolling upland. A little above this creek, the river narrowed abruptly to a gateway about 18 feet wide and over 300 feet high, and a little farther on to another gateway about 36 feet wide. Beyond this the river was wider, but the gorge was so much obstructed by avalanche barricades of icy hard snow blocks that it was scarcely possible to take a loaded sled over them, so we decided to camp there, cache all but four days provisions, and scout ahead with a very light sled.

Before going farther up the river, we explored the tributary creek, got out of the creek canyon about 2 miles up, and went up on the hills. The deep canyon of the river, cut down more than 300 feet through the dolomite, is not visible at a distance of more than half a mile. The country appeared to be slightly rolling, and sloped gradually north to the coast. The river canyon was seen to make a series of intricate bends a little above the creek, the loops coming near together. A little farther up, the river has quite a steep descent, with some rapids, if not waterfalls. The snowdrifts and ice barriers were so deep, however, in most places, that it was impossible to see the character of the river bed. In some stretches of the river, progress was only made by climbing over one rugged hill of snow blocks, descending 20 or 30 feet into a deep pit, and immediately ascending another ridge, like working through pressure-ridge sea ice. We frequently had to boost and lift the sled up over ridges by main strength, and take the dogs out of harness to let the sled down. The rock strata are horizontal in most places, with some slight local variations of not more than 4 or 5 degrees. Quartz geodes, with brown and transparent crystals of topaz, were numerous. In some parts of the canyon the sensation is something like that experienced at the bottom of a New York Street canyon with sky-scrapers towering on both sides.

After going about 20 miles in the canyon, we came out suddenly on a snow-covered, hilly country, and at the mouth of a large creek coming from a northerly direction, about 7 miles from mount Davy. A short distance south of the big canyon, there is a small canyon, about $\frac{3}{4}$ mile long and 20 to 30 feet deep, cut through dolomite overlain with gravelly knolls. At the upper end of the

little gorge, the river cliffs are overlain with a sort of mud conglomerate—fragments of dolomite, granite, and diabase, embedded in yellowish-grey mud or clay. The tops of all the hills are covered with small stones, little angular fragments of dolomite, and a few boulders of granite and diabase. The ground is very barren everywhere, and gravelly where exposed through the thin crust of snow on the hilltops; no ground-willows were seen, and very scanty grass.

Mr. Chipman went to the top of mount Davy, which is the most conspicuous landmark from the coast from the Inman river to some distance west of Croker river. He saw no rock exposures, the mountain being a hemispherical mound of gravel about 200 feet above the general level of the surrounding plain. Mount Davy has an elevation of about 2,000 feet above sea-level by aneroid, agreeing very closely with its height as determined by triangulation from the coast. Some hills southward appear to be higher than mount Davy. The Croker River valley extends comparatively straight south from here for 10 or 15 miles. The hills south and southwest of here form a rather rugged-looking range running approximately east and west. They are similar in appearance to the rather steep gravel ridges and knolls common along this coast, and no rock exposures were seen. Above the little upper canyon, the river is rather broad for a distance, looking like a lake, and on the east side of this expansion is a low, broad, stony, and gravelly flat. The only signs of life seen on the whole river trip were an Arctic fox track near mount Davy, a few Arctic hare tracks, and one hare which we killed. One raven was seen near the mouth of the river. We later learned from the missionaries that a few caribou came down to the coast a little east of here in the month of May. The country, however, seems to be too barren to afford sufficient pasturage in the winter. We returned to the coast March 24, and reached Bernard harbour April 2. The coldest weather of the winter was recorded while we were in camp up the Croker river, 46 degrees below zero Fahrenheit at 6 a.m., March 21. The thermometer rose to 9 degrees below zero at 4.30 p.m. the same day.

D. Jenness, ethnologist of the expedition, accompanied by Mr. H. Girling, and Patsy Klengenberg, interpreter and assistant, left Bernard harbour February 15, and returned late in March. They visited a number of Eskimo villages on the ice of Coronation gulf east of cape Krusenstern (Nuvuk), near Tree river (Kogluktualuk), and near Hepburn island (Igluhugyuk), meeting a considerable number of Eskimos who had not been seen before, and gaining considerable information in regard to the Kilusiktogmiut, who inhabit the Arctic Sound and Bathurst Inlet region, usually in summer; the Havuktogmiut, from the central part of the coast to southern Victoria island; the Ekalluktogmiut, from farther east than the Havuktogmiut; and the Umingmuktogmiut and the Asiagmiut, from the eastern part of the Bathurst Inlet region. They visited several villages on the ice about as far east as cape Barrow. A number of the eastern Eskimos came to the Bernard Harbour station about the same time that Mr. Jenness returned, and many interesting gramophone records of the language and dialects were obtained. During the winter, some Eskimos came from a considerable distance to visit the station, notably, a man named Kakshavik or Kakshavinna, calling himself a Pallirmiut, who had come from the northwestern side of Hudson bay, having been two winters on the way. He claimed to have traded with white men at a post far to the eastward; from his description, apparently around Baker lake.

F. Johansen, naturalist, with Adam Ovayuak (Eskimo) for an assistant, made a trip along the south shore of Victoria island, leaving the station March 6, and returning April 11, 1916. They crossed by way of the Liston and Sutton islands, Lady Franklin point, Miles islands, and went along the Richardson islands as far as Murray point, on the south shore of Victoria island. No Eskimos

were seen except one group camped on the ice near cape Murray. Mr. Johnasen made such botanical collections as were possible at that season, took a few zoological specimens, and a number of specimens of rock at various points along the south shore of Victoria island. A few caribou were seen on southern Victoria island on March 19 and 21. The most important results of his trip were a number of species of fossil corals collected on one corner of Liston island in Dolphin and Union strait, as recognizable fossils are very hard to find in that whole region. After his return, Mr. Johansen spent the rest of the season in biological investigations near Bernard harbour, and in packing specimens and equipment preparatory to going out. His collections of plants and insects were practically complete, and he made large collections and extensive studies of fish and marine and freshwater invertebrates.

John J. O'Neill, geologist, and John R. Cox, topographer, started from Bernard harbour on March 17, 1916, to survey the copper-bearing area in the Bathurst Inlet region. They took with them two sleds, so that they could work separately when desirable, and provisions for about ten weeks. They had for assistants Ikey Bolt, an English-speaking Point Hope Eskimo who had been with the expedition for over two years, and a Coronation Gulf Eskimo family who had proved very useful for work, and who were familiar with the Bathurst Inlet territory. They succeeded in carrying out this work very much as planned. Tracing the southern contact of the copper-bearing diabase with the older rocks to Kannuyuk island, it was not thought advisable to use the limited time at the disposal of the party in running a coast survey line to the southern tip of Bathurst inlet, and the time was spent in making a more complete geological sheet of the mainland and islands in the upper northwestern portion of Bathurst inlet. Over two hundred islands were mapped in the region generally covered in the charts by Chapman, Lewes, and Marcet islands. The group consists of many small rocky islands which at a little distance have the appearance of forming a continuous coast-line.

Practically no game was found in that region in March and the early part of April, and no natives living much south of cape Barrow at that season. The Eskimos say that the sealing is very poor in Bathurst inlet in winter and they go out on the ice farther north and west. The season seemed to be much later than it was in Dolphin and Union strait, as the seals did not begin to come up on the surface of the ice until about May 20. The provisions of the party held out well, as they obtained plenty of caribou after April. For fuel they used mostly distillate from the Cape Barrow cache, burning it in Primus stoves, but later in the spring used some dwarf willow from the islands. Early in the season they found the Eskimo snow-house and blubber-lamp useful on occasion.

The work of O'Neill and Cox in March, April, and May, 1916, completed the survey east of cape Barrow practically as planned. Mr. O'Neill summarizes the results of the work in that region as follows:

"The copper-bearing rocks in Bathurst inlet occur on most of the islands west of a line running northwest-southeast from the east side of Lewes island, and north of Kannuyuk island. They cover most of Banks peninsula and the western mainland shore from the mouth of Hood river to Moore bay, extending as much as 5 or 6 miles inland from the coast. These rocks are amygdaloids and form several successive layers which represent progressive, intermittent effusions of lava. Nearly all of them are impregnated with native copper over wide areas. The copper occurs in veins and in amygdules, and is disseminated as pepper throughout the groundmass. I have made a very conservative estimate of the amount of this copper-bearing rock (in which I actually saw native copper) and it seems that two billion (2 by 10^8) tons is well within the limit. It will be necessary to

wait for analyses and for the plotting of the map to give a close estimate of the value of these deposits."

Kenneth G. Chipman, with Eskimo camp assistants, and Corporal W. V. Bruce as voluntary aide, left Bernard harbour on April 12, 1916, to finish the survey of the south side of Coronation gulf east from the mouth of Rae river (where John R. Cox left off in 1915) to cape Barrow. Mr. Chipman completed the survey up to cape Barrow by May 20. The Bathurst Inlet survey parties were met here at an appointed rendezvous, and we all went west together to the mouth of the Coppermine river.

After returning from the Croker River survey trip, I spent some time at the station arranging for the spring work, and getting all accumulated zoological specimens taken care of before warm weather, and I finally started east with a sled and one Eskimo boy as assistant, to make a trip into the Arctic Sound and Bathurst Inlet region to investigate the occurrence of the Musk-ox, and other distributional problems of the fauna, as well as to look up and assist the various surveying parties on their return. Mr. J. E. Hoff, chief engineer of the *Alaska*, with Mike, his Siberian Eskimo assistant engineer, went along as far as Tree river, where they took out the launch motor and the Evinrude motor, and hauled them back to Bernard harbour. The hull of the launch was abandoned as it was badly worn, and the skin umiak was left for the last sled party to take back. The skin umiak is very practicable for crossing leads in the early summer, and I considered it advisable to have one on board the *Alaska* in case of accident in ice-crushes when travelling to cape Barrow. The umiak is light and may be readily hauled over the ice where a wooden boat would be stove.

The snow began to melt on the land much earlier than we had anticipated, being quite soft by May 19, and I could not make the projected inland trip south of Arctic sound. I met O'Neill and Cox in Bathurst inlet, and returned to cape Barrow with them, meeting Mr. Chipman's party again on May 21. There was much water on the ice around cape Barrow May 21, and much slush and water until we got back to Tree river. West of that point, most of the snow water had drained off through cracks in the ice, making travelling much better. The section of the coast from the Coppermine river to Port Epworth lies as mapped on the old charts. There are three fairly large rivers flowing into Gray bay, the most western being the Annielik (incorrectly indicated by Hanbury as the Unialik), and next the Kogluktuaryuk and the Utkusikaluk (the latter having been charted at its mouth by Sir John Franklin in 1821 as the Wentzell river). All of these rivers have rapids or falls a few miles from the coast, where the Eskimos usually have their summer fishing stations just below the rapids. Inman harbour was found to be a very deep and narrow fiord, being separated by a low portage of half a mile from another deep inlet running in from the east side of cape Barrow nearly making an island of the cape Barrow peninsula.

The local Eskimo name for cape Barrow is Haninnek. The rocks in the vicinity of cape Barrow are all granitic, and are not nearly so high as reported by Franklin.[1] He says: "The higher parts attain an elevation of 1,400 or 1,500 feet, and the whole is entirely destitute of vegetation" (July 20, 1821). We found the height of the highest granite ridge near the coast to be 340 feet by aneroid; and although the hills looked to be barren on their summits and sloped, the narrow valleys and gullies, where a little soil had collected, as well as the basins in the rock, around the little lakes, were filled with green grass, deep tundra moss, and cotton-grass or "nigger-head" tussocks; heather grew luxuriantly on many shelving rocks, and about ten species of flowering plants were found in

[1] Journey to the Polar sea, 1819–20–21–22.

bloom on August 13, 1915. The summits of the granite ridges were usually covered with grey lichens.

The united sledge parties returned together along the coast as far as the mouth of Coppermine river. Kenneth G. Chipman left the party at this place on June 1, to pack across country to Great Bear lake and go out via Fort Norman and Mackenzie river. He was accompanied by Mr. D'Arcy Arden, who had come down to Coronation gulf in May, 1916, with Inspector C. D. LaNauze's police patrol. Mr. Chipman reached the end of the telegraph line at Peace River Crossing on August 18, and Ottawa about the end of that month. Mr. Chipman decided to go out by the overland route because his work was finished, and the prospect was good that he could get out a little sooner by that route, and because it was desirable to have news of the southern party's condition and welfare get outside, in the event that the remainder of the party on the *Alaska* was prevented by shipwreck or ice conditions from getting out by way of cape Barrow and Nome, Alaska.

The rest of the party returned from the mouth of Coppermine river to the station at Bernard harbour, going a little out of the way to re-examine some geological formations at cape Kendall and cape Hearne, on the west side of Coronation gulf. We reached Bernard harbour June 6. Mr. George H. Wilkins, with the Herschell Island Eskimo, Palaiyak, reached Bernard harbour on June 15, having come by sled from the headquarters of the northern party of the expedition. He brought news of the safety of the three vessels of the northern party, and of the progress of the work of the party. At that time the northern party contemplated staying in the north until 1917, and later reports indicate a possibility of their staying until 1918. The northern party was stated to have provisions for one or two years, and were killing and storing away large quantities of caribou and musk-ox meat in the spring of 1916. The remainder of June and the early part of July were spent in completing collections in the vicinity of Bernard harbour, and assembling and packing specimens, stores, and equipment for shipment out of the Arctic.

Space had to be much economized on the *Alaska* going out, as far as Herschell island, as we had to bring out twenty-seven people on the small schooner, viz., eleven white men, including six members of the scientific staff, a crew of three, and two Mounted Police; fourteen Eskimo employees—seven men, three women, and four children; and two Eskimo prisoners held by the Mounted Police for homicide. In addition to this we had to take the Eskimos' personal camp gear and dogs, stores for paying off native employees at Baillie island and Herschell island, and enough reserve provisions to provide for the wintering of as many men as might remain with the *Alaska* to take care of the vessel and to bring her out next year should we be prevented by ice conditions from sailing from Dolphin and Union strait to Nome in the summer and autumn of 1916. I also thought it necessary to keep the skin umiak, two sleds and two teams of dogs on board, at least as far as cape Barrow, Alaska.

In September 1915, Corporal W. V. Bruce came in from Herschell island, on the *Alaska*, to work on the case of the disappearance of Père Rouvier and Père LeRoux, from the mission at Fort Norman, who had gone into the country north-east of Great Bear lake in 1913, and had not been heard of since. In May, 1916, Inspector C. D. LaNauze came down to Coronation gulf with a patrol from his winter quarters near old Fort Confidence on Dease river; and in the spring the police made prisoners of the two Eskimos, Sinnisiak and Uluksoaq, who had been concerned in killing the two priests. We took the inspector and the corporal with their two Eskimo prisoners out as passengers on the *Alaska* from Bernard harbour to Herschell island. All relations between the Royal North West Mounted Police and the expedition have been most cordial, and while with the

expedition both Inspector LaNauze and Corporal Bruce did everything they could as volunteer assistants in whatever work was going on. The members of the expedition have also had many courtesies and much assistance in their work from the detachment at Herschell island during the past three years.

The *Alaska* left a large permanent cache of provisions in the house formerly occupied by the southern party at Bernard harbour, in the event of any parties coming down from the northern party next winter. The house was left in the custody of Rev. H. Girling, who wintered near Clifton point with the mission schooner *Atkoon* and will establish a mission station at Bernard harbour the present season. This ensures our provision cache being protected from marauding natives.

The Hudson's Bay Company's schooner *Fort McPherson*, with Mr. W. G. Phillips in charge, sailed from Herchell island, July 21, 1916, after our arrival there, for the purpose of establishing a permanent trading post for the company at Bernard harbour. As there are now new trading posts of the Hudson's Bay Co. at Herschell island (69° 34′ north, 138° 54′ west), at Kittigazuit (east branch of the Mackenzie delta), at Baillie island (70° 35′ north, 128° 05 west), and at Bernard harbour (68° 47′ north, 114° 50′ west), any parties from the northern party of the expedition who may come to the mainland coast east of Herschell island will have little difficulty in getting provisions. The large amount of Canadian Arctic Expedition stores remaining at Herschell island were mostly landed by the *Ruby* after the *Alaska* had taken her required stores and sailed east again in 1915, and Mr. Stefansson's vessels had also taken what they were able to carry.

The work of loading the *Alaska* was begun in the summer of 1916 as soon as the vessel was loose from the ice in which she had been frozen all winter, and we succeeded in getting out of Bernard harbour much earlier than was anticipated. In the summer of 1915, prolonged northwesterly winds in the latter part of July had caused a local jam of ice in Dolphin and Union strait, and the *North Star* was not able to get away from Bernard harbour until August 9.

The *Alaska*, with all members of the southern party on board, left the headquarters of the past two years, at Bernard harbour, at 7.30 p.m., July 13, 1916, and after working through some loose areas of bay ice, reached the vicinity of Young point on July 17. Here we met with masses of floating ice too heavy for us to progress through. We were delayed near Young point for several days, tying up to heavy grounded cakes of ice along the beach, and were obliged to shift our position frequently because the ice-floes behind which we were sheltered shifted their position frequently as the tide rose and fell. The smooth rock bottom along the coast in this region prevented the big ice masses from grounding as hard and fast as they are accustomed to do on the mud and sand bottoms which are found farther west.

We got under way again in the evening of July 21, and worked out into a broad lead of open water outside the strip of loose, moving ice masses which was pressing down along the mainland shore on the south side of Amundsen gulf and Dolphin and Union strait. After getting through this shore ice, we found it did not extend much west of Croker river, and that the ocean was practically open westward. We reached Pierce Point harbour about midnight July 23, crossed Darnley bay, and reached cape Parry on the morning of July 24. We stopped at cape Parry for a short time to get a time observation, and then went ahead across Franklin bay, reaching cape Bathurst (or Baillie island) at 10.05 p.m. the same evening.

At Baillie island, I discharged and paid off Ikey Bolt or Angatitsiak (Point Hope Eskimo), Mungalina (Baillie Island Eskimo) and Patsy Klengenberg,

interpreter. They were paid principally in stores. There was a heavy northwest gale while we were in the shelter of the cape Bathurst sandspit on July 25 and 26. We left Baillie island at 7.00 p.m., July 26, and reached Herschell island 2.30 p.m., July 28, having been bothered very little by ice anywhere west of Croker river.

At Herschell island I landed some surplus stores from the *Alaska*, including 1,050 lbs. of pemmican, 250 lbs. rolled oats, 1 bbl. beef, 412 lbs. tobacco, and some miscellaneous equipment, storing them with the other expedition stores at Herschell island, in charge of the Royal North West Mounted Police, retaining on board the *Alaska* enough provisions to winter a certain number of men in case the vessel should be caught again by ice on the north coast of Alaska. I made as complete a survey of Canadian Arctic expedition stores at Herschell island as the time would permit. The provisions there, at the time we left, exclusive of a certain amount set aside to be shipped to Banks island, were as follows:

Rolled oats, 108 50-lb. cases	5,400 lbs.
Sugar, granulated, 6 50-lb. boxes	300 "
Sugar, granulated, 5 200-lb. boxes	1,000 "
Sugar, granulated, 20 100-lb. bbls	2,000 "
Dog biscuit, 11 50-lb. cases	550 "
Cracklings, 55 50-lb. cases	2,750 "
Rice, mostly brown, 36 50-lb. cases	1,800 "
Beef, 1 bbl	100
Total	13,900 lbs.

Acting in consultation with Mr. George H. Wilkins, who had recently come down from the northern party, and was conversant with their resources and their needs, we set aside certain provisions, and other equipment, and requested the Mounted Police to ask any whaling or trading vessel which might come in 1916, and intended to cruise in the vicinity of cape Kellett, Banks island, to take these stores and land them there for the benefit of the northern party. Mr. Wilkins reported that the three Stefansson vessels, the *Polar Bear*, *Mary Sachs*, and the *North Star*, are well supplied with most of the staple articles of food, but would be able to make use of the pemmican and some other things if they stayed another year, as seemed probable at the time. Provisions as follows were, therefore, requested to be sent to cape Kellett:

Pemmican, man, 17 50-lb.	cases,	850 lbs.
Pemmican, dog, 4 50-lb.	"	200 "
Cracklings, 20 50-lb.	"	1,000 "
Rolled oats, 6 50-lb.	"	300 "
Brown rice, 6 50-lb.	"	300 "
Sounding wire, 1 coil.		
Miscellaneous equipment.		

I have recently received information from Inspector LaNauze, Herschell island, that the above provisions and other miscellaneous equipment were taken by Captain C. T. Pedersen, steamship *Herman*, of San Francisco, and landed at cape Kellett, Banks island, in the latter part of August, 1916.

At Herschell island, I discharged and paid off the remaining Eskimos in the employ of the southern party, including Mike and wife; Ambrose Agnavigak and wife Unalina; Adam Ovayuak; and Silas Palaiyak; paying them as far as possible in stores remaining on board the *Alaska*, and partly in cash. The *Alaska* left Herschell island westward on August 3, 1916, at which date no ship had yet arrived at Herschell island from the westward. We had on board nine men: Daniel Sweeney, sailing master; J. E. Hoff, chief engineer, James Sullivan, cook; scientific staff: J. J. O'Neill, geologist; J. R. Cox, topographer;

D. Jenness, ethnologist; F. Johansen, biologist; George H. Wilkins, cinematographer and photographer; and Rudolph M. Anderson, zoologist, in command.

Very little ice was seen east of Herschell island, but this was heavy although somewhat loose and moving freely, from the International Boundary (141st meridian) practically all the way west to cape Barrow, Alaska. We stopped long enough at the 141st meridian boundary monument to get a time sight. One ship was seen on the way in, the *Herman*, Captain C. T. Pedersen, of San Francisco, but we could not speak to her as she was in the ice outside of Cross island, Alaska, on August 5, 1916, while we were inside of the islands. On account of the heavy ice outside, we again availed ourselves of the very excellent detailed mapping and sounding done by Mr. E. deK, Leffingwell, and went into the inside passage behind the chain of islands west of Flaxman island, coming out again between Midway island and Return reef. The channel inside of these low islands is rather shoal, but is valuable for vessels drawing not more than two fathoms. The ice pack was heavy around cape Barrow, and we had some difficulty in getting through, but after passing cape Smyth no more ice was seen. We left cape Smyth, which is only about 5 miles south of cape Barrow, and the site of the village of Barrow, the most northerly United States post-office on August 8, 1916.

No ice was encountered south of cape Smyth, Alaska, and we had a good run down to point Hope, where we stopped for a short time on August 10. Continuing across the outside of Kotzebue sound, we reached cape Prince of Wales and passed through Bering strait into Bering sea at the beginning of a heavy, prolonged northwest gale, on the evening of August 11, 1916. As the gale continued we were obliged to anchor for some time under the bluffs at cape York and Tin City, and again behind Sledge island, reaching Nome roadstead about 5 a.m., August 15, 1916.

The *Alaska* had not been leaking at all before passing cape Barrow, but after that began to leak badly around the stuffing-box; this necessitated considerable pumping to keep the engine room from being flooded and put out of commission. Although the weather was a little rough when we reached Nome, I succeeded in getting the cargo of specimens and stores lightered ashore that day and put on the Sesnon Company's (Alaska Lighterage and Commercial Company's) wharf. It was too rough to make any repairs on the vessel, and as the weather was rougher the next day, August 16, the *Alaska* was compelled to run 16 miles to the shelter of Sledge island. Three sailors had been temporarily engaged upon our arrival at Nome and the six members of the scientific staff were relieved from seaman's duty and allowed to go ashore. The storm abated somewhat on August 18, and the *Alaska* returned to the roadstead, but the surf was still too heavy to make a landing. The *Alaska* was ultimately hauled up high and dry on the beach at Nome and left in the charge of the Alaska Lighterage and Commercial Company for ultimate disposal by the Department of the Naval Service.

The extensive collections made by the party in geology and mineralogy, ethnology and archæology, terrestrial and marine biology, photography, botany, and the records and papers of the southern party were thus landed safely at Nome. As it was considered much safer to ship the results of our three years' work out by the regular freight and passenger service from Nome than to risk taking them down on the north Pacific to Victoria on a small vessel like the *Alaska* in the autumn season, all the collections, scientific instruments, and what equipment was worth shipping back, was transshipped to Seattle on the steamship *Northwestern*, of the Alaska Steamship Company. The members of the party also took passage to Seattle on the same steamer, leaving Nome August 27, and reach-

ing Seattle via the inside passage on September 11, 1916. All collections were received safely in Ottawa, in October, 1916.

To summarize: the scientific work of the southern party was completed substantially as outlined in our plans of last year, and all members of the party feel that in the main the results of their work for the past two years at least, have been as satisfactory and extensive as they anticipated, considering the difficulties encountered in working in such a remote field.

The two topographers of the southern party, Kenneth G. Chipman and John R. Cox, have completed the survey of the mainland coast in detail, on the scale of 10 miles to the inch, from the Alaska-Yukon Territory International Boundary (141st meridian), to Mackenzie river, made a traverse of Firth river, Y. T., surveyed the eastern and western branches of the Mackenzie delta and the mainland coast from the west side of Darnley bay (cape Parry peninsula) to a point well down into Bathurst inlet (south of Kannuyuk island), including a large number of the islands in the Coronation Gulf and Bathurst Inlet region. Several of the hitherto unexplored rivers in this region have been traversed, including one of the large rivers flowing into Darnley bay, Croker river flowing into Amundsen gulf, Rae river and Tree river flowing into Coronation gulf, and Hood river flowing into Arctic sound. Collinson Point harbour, Alaska (69° 59′ north, 144° 50′ west) and about 10 square miles surrounding it, and Bernard harbour, Chantry island (68° 47′ north, 114° 50′ west) and the country immediately surrounding these places; have been surveyed on the scale of $\frac{1}{24000}$ and mapped with 20-foot contours. The geological features have been investigated by J. J. O'Neill, and the relations of the different formations studied in detail at the most important points of contact. The most important result of the geological investigations was the detailed mapping and estimation of the available copper-bearing rock in a great new area hitherto very slightly known in the Bathurst Inlet region.

D. Jenness, ethnologist and anthropologist of the party, has made extensive ethnological and archæological collections, and about one hundred gramophone records of folk-lore, language, dance songs, and shamanistic performances, with careful transcriptions and translations of them. He has made a collection of cats'-cradle games from the different Eskimo tribes, numbering over one hundred and forty. Their language and vocabulary, the manners, social and religious customs, games, amusements, and general culture have been carefully studied and the information recorded. With the present rapid advance of civilized ideas and customs into this particular region, it is certain that much of this information could not be obtained at a later time. F. Johansen, marine biologist, entomologist, and botanist, has made extensive collections in all these branches, from northern Alaska and Canada. He has succeeded in rearing and working out the hitherto unknown life histories of a number of little known Arctic insects, and made many interesting and successful sea dredgings and soundings. Mr. George H. Wilkins has made many studies with camera and cinematograph, of Eskimo life, natural history objects, and Arctic scenery and topography.

In mammalogy and ornithology, fairly complete collections were made in the regions traversed, although the difficulties of transportation and the pressure of other duties often prevented the obtaining of as large series as might be desirable. The collection of birds numbers six hundred and nineteen (619) specimens, including seventy-three (73) species. The collection of mammals numbers four hundred and thirty-one (431) specimens, including twenty-two (22) species and probably several more subspecies. It is not possible to tell without more detailed examination whether any new forms are represented, but many specimens represent seasonal changes of plumage and pelage which are rare in collections, and the specimens taken will largely extend the geographical range of a number

of species. The notes on the life histories and ecology are also important. This branch of the work was in charge of R. M. Anderson, but all members of the expedition aided materially in bringing in specimens and notes.

A mere list of the different groups represented in the expedition's biological collections indicates something of their scope:

Mammals, Birds, Fishes, Insects, Plants, Crustaceans, Echinoderms, Sponges, Cirripedes or Barnacles, Molluscs, Hydroid Zoophytes, Medusæ and Ctenophores, Alcyonarians and Actinians, Algæ, Protozoa (Foraminifera and Radiolaria), Plankton, Sporozoa, Diatoms, Infusoria, Pteropods, Cephalopods, Decapods, Phyllopods, Copepods, Schizopods, Amphipods, Isopods, Pantopods, Annelids, Platyhelminthes, Rotatoria, Nematodes, Nemertines, Malacostraca, Bryozoa, Ascidians, Peridiniales, Ostracods, Hirudinea, Chaetognatha, Polychaeta.

To arrange for having the different biological groups worked up and the reports adequately published, an Arctic Biological Committee has been appointed jointly by the Department of the Naval Service and the Geological Survey. The members of the Committee are: Dominion Commissioner of Fisheries, Professor E. E. Prince, as chairman; Professor A. B. MacCallum of Toronto; Dominion Entomologist, Dr. C. Gordon Hewitt; Mr. James Macoun, Botanist, of the Geological Survey; and R. M. Anderson, representing the Canadian Arctic expedition and the zoological division of the Survey. The specimens to be worked up represent over forty distinct groups, each of which will require a separate chapter or report. Some of the larger groups, such as the insects, have been divided among several different men, mostly in the entomological division of the Department of Agriculture. A great many of these collections represent specimens of groups which have never been collected anywhere in the western Arctic area, and practically all of them are from districts and localities which are practically unrepresented in collections anywhere, from regions never before visited by a collector.

As far as possible these collections are being worked up by Canadian specialists, but some groups have necessarily been sent away because there was no satisfactory material in Canada for comparison. The Smithsonian Institution is well supplied with Alaskan Arctic material in some groups, and the British Museum with material from various Arctic expeditions, while the Greenland region is best represented by Danish and Norwegian collections; consequently, certain groups are being sent to some of these countries for determination. When the collections have been properly determined and worked, Canada's Museum will have a good start in a representation of the productions and content of a very large area that has hitherto been very poorly represented. The specimens are being placed in the hands of the best available specialists, and these men have shown a gratifying willingness to do what they can to help unravel the problems presented; so that we have satisfaction in knowing that such additions to knowledge as were obtained by the Canadian Arctic expedition of 1913-1916 may soon be available to the public of Canada and to the world.

Full meteorological observations have been kept up for three years, with barograph; thermograph; maximum, minimum, and standard thermometers; mercurial barometer, and anemometer. Continuous tidal observations were taken for some time during the winter in Dolphin and Union strait, in the vicinity of Bernard harbour, but outside of the islands, so that the flow of the tide would be unobstructed. Readings were taken on a graduated pole, every half hour, day and night, and at intervals of ten minutes and oftener around the periods of high and low tides. Fuller reports of the various scientific activities of the members of the expedition are in course of preparation and will be transmitted to the departments later.

Geological Report: Canadian Arctic Expedition.

(*J. J. O'Neill.*)

GENERAL STATEMENT.

The work of the southern party of the Canadian Arctic expedition up to August 1915 has been described in the Summary Report for 1915.

The remainder of that summer was spent in making a reconnaissance into Bathurst inlet, and the western coast and central islands were examined and mapped. Since the only boat available for this work was an 18-foot launch, more than half the time was wasted on account of storms. It took more than two weeks to return to Port Epworth, where the general freeze-up occurred on October 2. The winter quarters of the expedition, situated at Bernard harbour, were not reached until November 9.

On March 17, 1916, J. R. Cox of the topographical division, and the writer left Bernard harbour for Bathurst inlet to complete the survey and investigation of the copper-bearing rocks in that region. We returned to headquarters on June 5 by sled, and the remainder of June was spent in completing work around Bernard harbour and in making preparations for the return to Ottawa. The expedition left Bernard harbour on July 13 on the *Alaska* and arrived at Nome, Alaska, on August 15; from Nome to Ottawa the regular transportation lines were used.

SUMMARY AND CONCLUSIONS.

The determination of the fossils brought back from the Arctic coast shows the presence of Silurian, Devonian or Carboniferous, and upper Eocene or Oligocene strata. Fossils from the surface formations show that the coast was inundated by the sea in Pleistocene time, to at least 500 feet elevation.

In the Bathurst Inlet region three series of sediments were found overlying the granites of the Laurentian shield. A series of amygdaloidal basalts overlies these sediments and this series was found to contain extensive deposits of native copper.

BATHURST INLET AREA.

Location and Area.

Bathurst inlet is shown on the maps between longitude 111 degrees and 108 degrees west and south from 68 degrees north latitude. It forms an embayment from the north into the great Laurentian plateau. The inlet is about 50 miles wide at its mouth and 90 miles deep, tapering to a point at the southern end on the Arctic circle. More than one hundred and fifty islands occur in this inlet and they range in size from a few hundred square yards to several square miles; most of these islands are bounded by cliffs, with deep water to the shore.

GENERAL GEOLOGY.

Table of Formations in Bathurst Inlet Section.

Descending:	Thickness, feet
Flows of amygdaloidal basalts containing native copper	460+
Erosional unconformity	
Quartzitic conglomerate, well bedded and partly cross-bedded	4,000+
Erosional unconformity	
Purplish shales and sandstones	100+
Erosional and structural unconformity	
Thin-bedded, light-coloured dolomites	2,000+
Erosional unconformity	
Pink granite	——
Intrusive contact	
Grey granite	——

The granites are the oldest rocks which were seen in place in the district; they contain many inclusions of schists and slates but the parent rock of these masses was not observed anywhere. The granites are of two ages, an older grey granite, intruded in every direction by a pink variety; the contact is well seen at cape Barrow. Both granites are coarsely crystalline and neither shows a gneissoid structure. Veins of pegmatite are common, and at Galena point thin veins of galena and of galena with calcite were found cutting the granite in several places.

Overlying the eroded surface of the granites is a series of thin-bedded, light-coloured dolomites more than 2,000 feet in thickness; this series had suffered deep erosion and some warping before the succeeding formation was deposited. Following the dolomites a series of purplish sandstone and shales was laid down and in turn eroded so that in some places it is altogether missing from the section; the maximum thickness observed was about 100 feet.

The third series of sediments is quartzitic conglomerate which has a thickness of over 4,000 feet. The groundmass is mostly of coarse grains of quartz and there are well-rounded pebbles of quartz, sandstone, and granite together with slabs of purple shale and light-coloured dolomite. The formation is well stratified, many of the beds showing cross-bedding.

The youngest rocks in the Bathurst Inlet region are a series of flows of basaltic lava more than 400 feet in thickness, which rest uncomformably on the quartzitic formation. They have a dip of about 6 degrees from the horizontal and form a shallow, basin-shaped syncline. The separate flows range from less than 30 to more than 150 feet in thickness, and there are two or three thin beds of sediment interbedded with the series. It is in these lavas that the deposits of native copper in this district occur.

Cutting through all the rocks in the region are dykes and sills of basic rock. These probably represent the channels through which the lavas reached the surface.

ECONOMIC GEOLOGY.

Native Copper.

The mineral of greatest economic importance in this region is native copper. It is found in most of the flows of amygdaloidal basalt, which cover an area of about 20 square miles on the mainland and about 50 square miles on the islands in Bathurst inlet. On Banks peninsula the total thickness of the lavas is about 460 feet, and native copper was actually seen throughout more than 350 feet of this thickness. A similar impregnation of copper was observed on the islands covered by these lavas.

The copper occurs in three forms in the amygdaloids:

(1) As vein copper, in thin fissures in the rocks.
(2) As amygdaloidal copper in irregular grains and small masses in the branching gas cavities near the surface of the flows.
(3) As disseminated copper in minute flakes scattered throughout the groundmass.

Nos. 1 and 2 are locally important, but No. 3 is the most widespread.

Vein copper occurs as thin sheets of native copper, and as small flakes and pieces scattered through a matrix of quartz, calcite, etc. A sample of the latter, from a ½-inch vein ran 4·56 per cent copper. In parts of the area this vein copper is quite important in amount but no attempt was made to estimate its relative importance.

Amygdaloidal copper is found in the upper portion of the flows where the gas cavities were numerous and a free passage was permitted to the mineralizing solutions. Only occasionally was this type visible for examination because of accumulations of talus or of snow along the cliff-face. A sample from one of the exposures gave 1·44 per cent copper, and 0·05 ounce (Troy) of silver per ton of 2,000 pounds. No estimate was made of the amount of this material available.

Disseminated copper occurs over the whole area of more than 1,000 square miles and practically through the whole thickness of the formation. Analyses of forty-five representative samples show that the values range between $\frac{1}{100}$ and $\frac{1}{4}$ of 1 per cent. This copper is in tiny flakes and can usually be seen with a lens.

A rough estimate of the amount of rock carrying values in native copper, neglecting those parts on the mainland where the copper content was not established, is as follows:

Banks peninsula, more than 10 square miles.

Islands, more than 50 square miles.

Using a minimum thickness, there are then more than 6,000,000,000 cubic yards of the rock. If it be assumed that one cubic yard is equivalent to one ton of rock, the available tonnage would be 6,000,000,000 tons.

Summing up then, there are in Bathurst Inlet area, more than 6,000,000,000 tons of rock carrying $\frac{1}{100}$ to $\frac{1}{4}$ of 1 per cent of disseminated native copper, and an unestimated amount of amygdaloidal copper running over 1 per cent; besides this there are veins cutting through the above rocks, some containing thin sheets of native copper $\frac{1}{64}$ to $\frac{1}{8}$ inch in thickness and others carrying over $4\frac{1}{2}$ per cent of flake copper.

It will require considerable detailed sampling to determine whether the total percentage of copper is sufficiently large to pay for working the deposits in whole or in part. When it is considered that copper values are found over the whole area of more than 1,000 square miles, it seems highly probable that there may be sufficient concentration in parts of the area to permit of economic mining.

Bornite.

In many parts of the southern half of the area of copper-bearing rocks in Bathurst inlet a series of dolomites immediately underlies the basalts; the upper few feet of this series is partly replaced by bornite in layers and in masses. Exposures occur in the cliffs which face the east or southeast, notably on the islands Kanuak, Barry or Ekullialuk, Igloruullig, and Algaq, and along the east base of Banks peninsula. The ore was seen in several places along these cliffs and an analysis of a sample from one of the layers gave 49·87 per cent copper and 1·12 ounces (Troy) of silver per ton of 2,000 pounds.

Sills and dykes of basalt are found throughout the copper-bearing area. Some of these are impregnated with bornite. An analysis shows 1·18 per cent copper in the rock. These occurrences of bornite may prove to be one of the more valuable sources of copper in this region.

Summary Table of Occurrence of Copper in Bathurst Inlet, N.W.T.

Type of deposit	Assays	
	Copper, per cent	Silver, ounces per ton
Disseminated copper occurring through the whole thickness of basalts over an area of more than 1,000 square miles	$\frac{1}{100}$ to $\frac{1}{4}$	....
Amygdaloidal copper occurring in the upper portion of some of the flows, amount unknown	1·44	0·05
Vein copper, thin sheets of pure copper	....	....
Vein copper, flakes of copper in matrix (veins less than 1 in. wide)	4·56	....
Sulphide replacement of dolomite carrying	49·87	1·12
Sulphide impregnation of sills of basalt carrying	1·18	....

Galena.

Thin veins of galena occur at Galena point, Bathurst inlet, cutting the granite. The veins are seldom more than 3 inches in width, or more than 20 feet in length, pinching out at both ends. Only four or five veins were seen in making a traverse of about 1½ miles across the point. An analysis of this galena shows only a trace of silver.

FOSSILS.

Fossil corals from the Liston and Sutton islands in Dolphin and Union strait have been determined by E. M. Kindle to be of Silurian age, about the horizon of the Lockport limestone.

The presence of post-Silurian strata near Tinney point, on the Arctic coast, is indicated by the presence of pieces of carbonized wood in branching cavities in a fine-grained, impure sandstone or silt.

Fossils collected from a partly consolidated sandy shale formation on a river which flows into Darnley bay about 15 miles south of cape Lyons, were determined by Dr. W. H. Dall, to be of upper Eocene or Oligocene age, and of probable estuarine origin. They are "probably contemporaneous with the leaf beds of Nenilchik on Cook's inlet, Alaska."

Fossils collected from the sand-gravel-mud formation which is found everywhere along the Arctic coast from cape Parry to Kent peninsula were examined by Dr. W. H. Dall, who says of them. "These fossils are without doubt all Pleistocene.......... and the horizon seems to be identical with that described by Schrader under the name of the Gubic Sand, on the north coast of Alaska." These fossils were found at intervals all along the coast and at elevations ranging up to 500 feet above sea-level.

TOPOGRAPHICAL DIVISION.

(*W. H. Boyd.*)

Topographers from this division who are serving with the Canadian Expeditionary Forces are: W. E. Lawson, S. C. McLean, and A. G. Haultain. The services of E. E. Freeland have been loaned for office work in the Department of Militia and Defence. Another member of the division, L. N. Richard, has enlisted with an overseas battalion.

K. G. Chipman and J. R. Cox returned in September from the Arctic and are now engaged in completing their report and map.

Field Work.

ANYOX MAP-AREA, BRITISH COLUMBIA.

F. S. Falconer in Charge.

The map-area covers 21 square miles and includes the town of Anyox, the Hidden Creek mines, and the Bonanza properties. Publishing scale of map 1,000 feet to 1 inch; contour interval 50 feet. R. Bartlett was attached to the party as topographical assistant. The other assistants were: J. A. Circe, J. F. Mellish, G. Wrong, and R. Hugo.

KANANASKIS-ELBOW MAP-AREA, BRITISH COLUMBIA AND ALBERTA.

D. A. Nichols in Charge.

This map-area, which is the fourth of the series of maps covering the Rocky Mountain coal fields, lies between latitudes 50° 30′ and 51° 00′, and longitudes 114° 30′ and 115° 30′ approximately. Publishing scale of map $\frac{1}{250000}$ or approximately 4 miles to 1 inch; contour interval 200 feet. H. M. Peck, J. F. Wickenden, and S. K. Payzant were attached to the party as assistants.

EASTEND MAP-AREA, SASKATCHEWAN.

A. C. T. Sheppard in Charge.

This map-area includes townships 5, 6, 7, and 8, ranges 20, 21, 22, 23, 24, 25, and 26, west of the 3rd meridian—28 townships in all. Publishing scale $\frac{1}{125000}$ or approximately 2 miles to 1 inch; contour interval 25 feet. C. L. Larson, C. M. Moore, and W. G. Brown were attached to the party as assistants.

NORTHERN ONTARIO EXPLORATION.

C. H. Freeman in Charge.

C. H. Freeman was engaged in making surveys of certain lakes and rivers along the route of the Canadian Northern Ontario railway in the vicinity of Foleyet. J. H. T. Morrison was attached to the party as assistant.

BEAUCEVILLE MAP-AREA, QUEBEC.

B. R. MacKay in Charge.

This map-area covers a strip of country, 6 miles in width, along Chaudière river between rivière du Loup and rivière du Bras. Publishing scale $\frac{1}{62500}$ or approximately 1 mile to 1 inch; contour interval 20 feet. H. M. Roscoe, H. Lavoie, W. B. Davidson, C. A. P. Larose, and J. Monette were attached to the party as assistants.

TRIANGULATION.

R. C. McDonald in Charge.

R. C. McDonald was engaged in extending the Rocky Mountains coal fields triangulation northward through the Kananaskis-Elbow map-area. Connexion was made near Banff and Kananaskis to the triangulation of the Railway Belt by the Department of the Interior. G. C. Monture was attached to the party as assistant.

BIOLOGICAL DIVISION.

BOTANY.

(*John Macoun.*)

As in the year 1915 so in 1916 my work was confined chiefly to the collection and study of cryptogams, especially fungi. With fungi as with mosses and lichens my collections have grown more important each year as my increased familiarity with the commoner species enables me to detect the rarer ones. As mentioned in previous reports the mild climate of Vancouver island makes it possible for me to collect at all seasons and many cryptogams are at their best in the winter. With the exception of three weeks spent at Brackendale in June, at the time my son was there, my work during 1916 was confined to the Saanich peninsula and the vicinity of Victoria. Brackendale being near the coast was an excellent place for cryptogams and many fine species were collected there which do not occur on Vancouver island. Now that I have a good microscope I am able to determine most of the mosses and lichens myself but I am in constant correspondence with specialists, all my lichens going to Mr. G. K. Merrill, Rockland, Maine, who has during the year described several new species for me. Although I have continued to correspond with many moss specialists the major part of my musci have in recent months gone to the Rev. C. H. Demetrius, Emma, Mo. Some important groups of fungi have been named for me by Mr. E. A. Burt, Missouri Botanical Gardens, St. Louis, Mo., but the bulk of my collections have gone to Dr. John Dearness, London, Ont., and I cannot speak too highly of the promptness and thoroughness with which Dr. Dearness has done his work, he having reported upon 1,000 specimens during the past two years, the great majority of which had never been recorded from British Columbia, as little collecting of fungi had been done there. Very many species new to science have been described by Dr. Dearness in mycological journals and several hundred pages of notes and descriptions made by Dr. Dearness are on file in the herbarium at Ottawa. I send the specimens direct to Dr. Dearness who sends his reports to my son at Ottawa where they are copied, the originals being kept there and copies sent to me. As no one is working on cryptogams at Ottawa the collections I have made during the past four years are at Sidney, as I require them for reference, but all will go to the Museum when they are needed or when I give up active work. As they are named, they are labelled, mounted, and placed in genus covers so that they are available for study at any time.

Although I do not collect many flowering plants I am constantly on the lookout for rare species and last year detected a minute grass, *Mibora verna*, which has not before been recorded in America. It is probably an introduction from France with garden seed. British Columbia botanists, especially those living near the coast, constantly consult me about difficult species, and I have been of not a little assistance to them.

BOTANY.

(*J. M. Macoun.*)

Since the date of his last summary report the greater part of the writer's time while in Ottawa has been taken up by the routine work of his division, which includes the determination of botanical specimens sent to him by correspondents and collectors from all parts of the Dominion. Lists are made and records kept of all important collections. These numbered 1,440 specimens

during the current year, of which 585, representing collections made in various parts of British Columbia, came from the Provincial Museum at Victoria.

Prof. F. J. Lewis of the university of Alberta was engaged last summer at Banff in botanical work for this department. Two hundred and ninety-five sheets of the specimens collected by him have been determined by the writer and also eighty sheets from the Great Slave Lake district which had been collected by C. F. Howe of the Alberta university staff. Through the kindness of Dr. Lewis a set of these plants has been presented to the herbarium, as well as a complete set of his own collection made in the vicinity of Banff. Several collections were brought in by members of the Geological Survey staff. The smallest, but at the same time the most interesting of these collections, was made by D. D. Cairnes in the Klotassin area southwest of Yukon river between Selkirk and White river. While numbering only twenty-seven species, at least half of these were species that, from our knowledge of the Yukon district would not have been expected to occur in the Klotassin region. Of these, three were new to Canada: *Cardamine Blaisdellii* known before only from Nome, a *Phacelia* that is apparently new to science, and a *Crucifer* of which we have not been able to determine even the genus as the specimens are immature. It is, however, not represented either in our herbarium or in New York where there are large Yukon and Alaskan collections. As an indication of the useful botanical work that may be done by geological parties in the field it may be stated that Mr. Cairnes in recent years has brought into the herbarium series of new specimens that have added greatly to our knowledge of the Yukon flora. A list of his plants appears in his own report. While with C. W. Drysdale in the Ymir district, B.C., in 1915, W. C. Sandercock made an extensive collection of plants which were named by the writer and of which a list has been published in Mr. Drysdale's Ymir report. Mr. Sandercock and Mr. Drysdale both made small collections in the Slocan district in 1916. These collections have been named and mounted but do not contain anything of special interest. They will serve as a basis for future work, however, and it is hoped that they will be added to by future collections made in the same region. Charles Camsell, when he visited the Wood Buffalo range southwest of Fort Smith last summer, brought back with him specimens of the principal forage plants of the region. These were named by the writer and the list is being published by the Dominion Parks Branch.

One of the duties, as it is one of the privileges, of the writer is to furnish information about Canadian plants to working botanists everywhere, and much of his correspondence has always fallen under this head. During the past year two important lists of plants were made, one of the writer's Skagit River collection made in 1905, the other of Prof. John Macoun's collection made at different times on Cape Breton island. The former list was published by Prof. John Davidson in the report of the Provincial Botanist for British Columbia, and the latter will be used by Mr. Geo. E. Nichols, of Yale university, New Haven, Conn., who is at work on a flora of Cape Breton island. Thesel ists were made by Miss M. C. Stewart under the writer's supervision.

Apart from the lists referred to above nothing was published during the year but a twelve page article in the Canada Year Book which was written in collaboration with Dr. M. O. Malte of the Central Experimental farm. Although brief, this article was the result of prolonged study of the flora of Canada by the authors and is a concise summary of their knowledge. This article is being reprinted as a Geological Survey Bulletin. From various sources 325 sheets of botanical specimens were received for the herbarium, and 135 sheets distributed. Five hundred and forty sheets, chiefly of Canadian specimens, were mounted. In all these lines much more would have been done had I botanical assistance of any kind. In addition to her usual duties Miss M. C. Stewart

has done much work in the herbarium during the year. While the writer was in the field she arranged and placed in cabinets our whole foreign collection which had never been unpacked since its transfer from the old Museum, and the sorting of specimens into the herbarium is now done by her.

FIELD WORK.

A small collection of plants brought from the Bridge River district by C. W. Drysdale in 1915 drew our attention to the unexpected character of the flora of that region, as several of the species were characteristic of the Rocky Mountain flora and had not before been recorded from either the Selkirk or Coast ranges. I, therefore, recommended that I be instructed to spend the season of 1916 in that district and along the line of the recently constructed Pacific Great Eastern railway between Squamish and Lillooet. As little was known of the fauna, I was permitted to take with me C. H. Young of this department and William Spreadborough who has for so many years acted as my field assistant. On June 8 we were in camp at Brackendale near the coast terminus of the Pacific Great Eastern railway, and remained there until the end of the month. From that camp a thorough examination of the flora between the coast and Mons was made, 354 species of flowering plants and many cryptogams being collected. These collections have not yet been studied but, except for extensions of range, not much of botanical interest was found so far as the indigenous flora is concerned. Many introduced species were noted and collected, however, some from the prairie, some from other parts of British Columbia, and a few from the United States. Most of these, perhaps all of them, were introduced while the railway was being constructed, as was evident from the fact that it was around old construction camps that they were most numerous, both as to the number of individuals and the number of species. On inquiry I learned that much of the hay used had been brought from the prairie provinces, evidently what is called "wild hay" as was shown by the variety of grasses and carices. Some of these have spread from the railway along trails and now apparently form part of the indigenous flora of the region. Special reference will be made to these species when my full report is published.

We moved camp to Lillooet July 1 with the intention of remaining there until the season was sufficiently far advanced to permit of our working on the mountains. This proved to be such an interesting locality botanically that we did not leave there until August 8. Lillooet is situated at the junction of Cayoosh creek and Fraser river. Within easy walking distance of camp we had the characteristic flora of the "dry interior" of British Columbia, typical Cascade Range plants, and a true alpine flora on the eastern slopes of the higher mountains of the vicinity. During the five weeks spent at Lillooet 489 species of flowering plants were collected, the largest number of species I ever collected in one locality in one season. In the Fraser valley itself not much of great interest was found, the flora being that which characterizes the arid parts of British Columbia; but many species were collected that had not been recorded north of the main line of the Canadian Pacific railway. The most interesting plant collected near Fraser river was *Parietaria pennsylvanica* Muhl. which grew near a spring. Within a few yards of it were *Opuntia*, *Artemisia*, *Chrysanthemums*, etc., certainly an unexpected situation in which to find an eastern species peculiar to damp shady situations. It was evidently indigenous. Advantage was taken of our being so long at Lillooet to make several trips to the summit of mount McLean. A good trail takes one to an altitude of about 6,000 feet and all the summits are easily accessible from that point. It was here that the largest number of Alpine-Arctic species were collected, although a few of the same

species were found later farther west on McGillivray creek on the higher summits. Nearly fifty species were collected that had not been recorded west of the Rocky mountains or south of Atlin, most of them, species which one would not expect to find in the Cascade range. While a small percentage of these species may be said to reach their southern limit at this place, the occurrence of most of them is in my opinion due to the fact that the hygrometric conditions are such as are found nowhere else in southern British Columbia. In the Selkirk mountains and the mountains of the Coast range south of Fraser river, both rain and snowfall are heavy, as indeed they are a few miles westward of the district under discussion; but, although the precipitation is very heavy in the Cascade range generally, it is comparatively light on the eastern slopes of the range. That there is little moisture in the air is also proved by the fact that during the summer months the snow may be said to evaporate rather than melt. In other words, the innumerable rivulets that one expects to see flowing from melting snow are almost wholly wanting above 6,000 feet, no matter how warm the day may be. The following are some of the most important and characteristic Alpine-Arctic plants found on mount McLean:

Several species of *Poa* and other grasses, nearly all the Alpine-Arctic *Carices*, *Juncaceæ*, *Cruciferæ*, *Caryophyllaceæ*, *Rosaceæ*, *Saxifragaceæ*, and *Ericaceæ*, and many individual species in other orders.

From our Lillooet camp several trips were made back along the line of the Pacific Great Eastern railway as far as Pemberton, the whole distance being covered at one time or another on foot. This afforded me an opportunity of noting exactly the range of characteristic coast plants eastward along the line of the railway and all important trees and shrubs as well as many herbaceous plants were recorded in this way.

Camp was moved August 8 to the forks of McGillivray creek, at an altitude of about 5,000 feet. This locality can be reached in a few hours by an excellent trail which ascends McGillivray creek from its mouth on Anderson lake, and I know of no more interesting locality for botanical work. Horses can be procured at D'Arcy and the trip from D'Arcy to our camping-ground and return may be made in a single day if one wishes to avoid the expense of horse hire by sending back the pack animals. Some idea of the great profusion of flowers growing in this place may be learned from the fact that I noted 89 species in bloom within a few yards of our camp. There is little variety in the vegetation found on the mountains of this district, nearly all the species collected having been found within 4 or 5 miles of camp, although our collecting trips covered a much larger area. This does not mean that the number of species is not great, but one branch of the creek flows to the east and the other to the south so that the mountains slope to every point of the compass and nearly all of the characteristic species of the Cascade range can thus be found within a short radius. Glaciers occupy many of the valleys which slope to the north and in such localities the flora is almost identical with that of the Selkirk mountains, while a mile or two away across the valley the vegetation more nearly resembles that of the Rocky mountains. Several species which are apparently new to science were collected both here and on the slopes of mount McLean.

We returned to Lillooet August 23 and a few days later moved camp back to Brackendale where I left Messrs. Young and Spreadborough while I went to Victoria and Sidney to work in the provincial herbarium and with Prof. Macoun. Nearly 800 species of flowering plants, among them more than 100 species of *Compositae*, were collected during the season besides many cryptogams. Mr. Young and Mr. Spreadborough were cheerful and indefatigable workers throughout the season and besides making a large collection of birds and mammals were of great assistance to me in my botanical work.

The most important collection that has come into the department in many years is that brought home by Mr. Frits Johansen, biologist attached to the Canadian Arctic expedition. Work was begun in the autumn of 1913 and continued until 1916, the collections covering the country between Alaska and Coronation gulf. Mr. Johansen's report appears on page below.

Very shortly after Mr. Johansen returned to Ottawa work was begun on his collections. The flowering plants were, with Mr. Johansen's assistance, sorted by the writer and provisionally named. The cryptogams were sent to specialists as soon as they were sorted. The mosses and hepaticæ went to the New York Botanical Garden and have all been named by specialists. The lichens went to Mr. G. K. Merrill, who is now at work on them, the fungi to Dr. John Dearness, London, Ontario, who has completed his first study of this group and described several new species. The algæ were divided into two lots, the marine material going to Mr. F. S. Collins, North Eastham, Mass., and the freshwater algæ to Mr. C. W. Lowe, Manitoba univeristy, Winnipeg. Both these gentlemen are making good progress in the determination of the specimens sent them and it is expected that complete reports on all groups will be in my hands before spring. While the phanerogams will require considerable study, I expect that my report on them also will be ready before May 1. Many of the orders have already been worked up and three genera which were well represented in Mr. Johansen's collection were sent to specialists who happened to be monographing these genera and to whom all our herbarium material had been loaned; the genus *Artemisia* to Dr. P. A. Rydberg, *Senecio* to Dr. J. M. Greenman, and *Cerastium* to Dr. M. L. Fernald. Dr. Rydberg has already reported on *Artemisia* describing two species new to science and recording the rediscovery of *A. Richardsoniana*.

Dr. Francis J. Lewis, professor of biology at the univeristy of Alberta, spent the season of 1916 in the vicinity of Banff where, in addition to making a large collection of botanical specimens, he mapped a considerable portion of the Banff National park for the purpose of illustrating the vegetation units represented in that district. This is the first work of the kind that has been attempted in Canada; similar work carried on in Great Britain by Dr. Lewis represents the earliest attempt to show vegetation units in that country. Apart from its great scientific interest and importance such work is of real economic value. It yields detailed information about the distribution of different types of forest and the accompanying ground floras, distribution in altitude, relation to soil, aspect, changes taking place over burnt areas of different age in different types of forest, information about the different kinds of grasslands and factors affecting their distribution such as soil, aspect, altitude, etc.

Canadian Arctic Expedition.—Botany.

(Frits Johansen.)

Summer of 1913, Teller, Alaska (Port Clarence).

A collection of flowering plants was made by Mr. James Murray, but later lost with the *Karluk* off Wrangel island. The botanical collections from Teller are, therefore, limited to a few mosses and lichens and freshwater plants, besides a fairly good representation of the marine algæ, which I got accidentally while making the zoological collections.

Winter 1913-14 and Spring of 1914, Collinson Point, Alaska.

While the expedition stayed here I devoted much time to a study of the conditions under which the plants occur on the coastal tundra and adjoining

islands all the year round. I made, in June and July 1914, rich and representative collections of plants of all orders and took many photographs. Occasional longer sledge trips were made along the coast east and west and up the Sadlerochit river inland. The botanical collections also include many freshwater and some marine algæ which I obtained while making zoological collections.

Mackenzie Delta, Y.T., August, 1914.

While the expedition spent a week or two at Herschell island, taking on supplies and sending specimens, etc., home, I found time to make a fairly representative collection of the flowering plants on the east end of the island and supplemented this with a few more plants and many photographs when we reached the island two years later. A small but valuable collection of flowering plants was made in August, 1914, by Messrs. Cox and O'Neill on the mainland opposite, at Shingle point.

Dolphin and Union Strait and Coronation Gulf, N.W.T., Autumn of 1914 to Summer of 1916.

While the expedition stayed at Bernard harbour, I made a large and representative collection of the flora in that region and of the country traversed on all the longer excursions (Coppermine river, Wollaston peninsula) that I made, besides taking many photographs. As at Collinson point, I particularly studied the biology of flowering plants (colours, shape, soil requirements, seasonal appearance) and their distribution. The collections also comprise many freshwater and marine algæ, which I got during zoological investigations. A small collection of flowering plants was made by D. Jenness on Wollaston peninsula and a larger one by Messrs, O'Neill, Cox, and Anderson along the south coast of Coronation gulf and Bathurst inlet, both during the summer of 1915, and at localities I did not get the opportunity of visiting myself.

On the way out we stopped for two days at cape Bathurst. N.W.T., and I there secured a representative collection of the more typical and valuable plants (*Phlox Richardsonii* a.o.), besides samples of the common, Arctic ones.

With the exception of a few big fungi (which rotted and had to be thrown away), all botanical specimens collected were brought safely to Ottawa, in spite of many trying experiences in drying them, saving them from melting snow, storing them for three years, and collecting on sledge trips in the winter. The collections would have been still better if I had not had the zoological work to do simultaneously, and if I had been able to visit more and different localities in the summer time; also this was my first experience as responsible botanical collector in the field. However, I am confident that my three years work forms a valuable contribution to our knowledge of the plants of hitherto little known regions in the far north. I desire to express my gratitude for the assistance given by the other members of the scientific staff during the expedition, and for the promptness with which the material has been received and looked after in Ottawa.

ZOOLOGY.

(*P. A. Taverner.*)

As the last report of this division included the year 1915 only to November 15 this one covers the remainder of that year and all of 1916.

Owing to the burning of the Parliament buildings early in February and the removal of the legislature to the Museum all exhibits were dismantled and

stored, and the space allotted to the division was much reduced. This was a serious interruption and caused an unavoidable congestion that has been reflected in all branches of the work.

In the office, correspondence and the care of incoming and other material have taken up much time. The writer has completed a popular book on the "Birds of eastern Canada," mentioned in the previous report, and it is now in the hands of the editor and is being prepared for press. In addition, various recommendations were made regarding game and bird protection to the Conservation and other Commissions and a paper was prepared on the faunas of Canada for the "Canada Year Book" for 1915, pages 55-62. Owing to the pressure of these duties little was accomplished in scientific investigation, but a number of interesting problems are being considered and some progress has been made with them. Miss Bentley has made considerable progress with a bibliography of Canadian ornithology.

The preparatory section during the summer collected, in the immediate vicinity of Ottawa, material enough to keep them busy through the winter. In this way a number of small species groups have been built and material for many more prepared, all of which have been stored for future exhibition. C. L. Patch has made a scale model of a proposed mammal hall for large, landscape, life-history groups of the most characteristic species of Canadian animals.

D. Blakeley has continued his work in remaking the great number of old bird skins that were rapidly deteriorating and preparing incoming specimens that demanded immediate attention.

J. A. Perrin has tanned a considerable number of large skins and has made them convenient for handling and study. At the present rate it will not be long before most of this valuable material will be rendered available for scientific use.

In storage and other equipment we have also made considerable advance. The economical use of confined space has made necessary the installation of space saving devices. The storage room in the basement, for large mammals and alcoholic specimens, has been fitted with a fireproof partition, and doors and racks have been installed for the convenient and safe storage of specimens. In the bird range (study collections) new cases have been installed. These new cases are of the type spoken of in previous reports and, while inexpensive in comparison with systems adopted by other institutions, are, in the opinion of those who have examined them, remarkably efficient and convenient. Similar cases are under construction for the small mammals under R. M. Anderson's care, and shortly both these collections will be in satisfactory order and condition.

Thanks to the assistance of the Entomological Branch of the Department of Agriculture, all the insects have been repinned in the steel cases previously provided for them, and while not arranged or classified therein are safe from deterioration and museum pests.

The alcoholic specimens have been gone over and arranged upon the shelves of the storage room previously mentioned. The storage condition of other material is less satisfactory. We have large collections of mollusca, crustaceans, and other invertebrates, but, owing to limitations of staff and storage space very little can be done to them beyond caring for their immediate welfare. It is to be hoped when normal times arrive that suitable arrangements will be made for the study and care of these important collections so that they may reach their fullest degree of usefulness.

Though the need of economy has been realized and our purchases reduced to a minimum the growth of our collections has been very satisfactory. There have been a large number of small donations during the year; and, while in number of individual specimens they may not be impressive, their widely scat-

tered sources indicate a growing interest in the institution that is very satisfactory.

A number of the officers of the Geological Survey, not directly connected with this division, have brought in collections obtained incidentally to their regular work. Geo. Sternberg collected a number of birds, including a fine series of young and adult Ferruginous Rough-Legged Hawks, also some fish that will be of great importance to future ichthyologists. I am informed by the Entomological Branch who are studying the collection of insects brought in by D. D. Cairnes that it is a most interesting one. Our thanks are due these gentlemen and others who of their own initiative found time to collect for us.

In December of last year (1915) and January of this, C. L. Patch collected in Barkley sound, Vancouver island. Besides the Sea-lions, the principal object of this trip, he secured a number of other mammals and a fine collection of winter sea birds that were very acceptable in our collections. Prominent amongst these are a fine series of Barrow's and American Goldeneye, Surf and White-winged Scoters, and Surf-birds. The Surf-birds were quite a surprise as this species has not heretofore been reported in winter north of South America. A fuller report of this expedition and its results appears on page 353.

C. H. Young was detailed to accompany a party under J. M. Macoun as zoologist and collector and spent the season in eastern British Columbia near the head of Howe sound, and in the lake Lillooet and Bridge River country. The latter forms one of the largest isolated areas of Hudsonian fauna and had not been previously visited by zoological collectors.

Mr. Young left Ottawa a little in advance of the rest of the party and spent from May 22 to June 2 collecting birds in the vicinity of Douglas, Manitoba. Though the season was too far advanced for obtaining the earlier migrants, and bad weather had to be contended with, he procured a representative collection of the birds of the locality. After this he joined Mr. Macoun and Wm. Spreadborough in British Columbia. The results of this trip were most satisfactory. A fuller report appears on page 358.

Very few specimens were purchased this year. The most important amongst those so obtained are two small collections made by John Goddard on the north shore of the gulf of St. Lawrence near Bonne Esperance. These being taken in a country difficult of access and between late autumn and the succeeding early summer, when it is difficult for ordinary collectors to reach the locality, made valuable acquisitions.

The most important accession of the year is the material brought in by the Canadian Arctic expedition.

The growth of the collections is reflected in the increased use that is being made of them by outside parties, both institutional and private. The Normal school in the city has availed itself of them extensively and has repeatedly borrowed specimens for use in instruction. Numbers of public museums borrowed specimens for use in research; among them are the United States Biological Survey, the Smithsonian Institution, and the Museum of Comparative Zoology, university of California, and the Entomological Branch of our own government. Numerous eminent private investigators have also appealed to the Department for the use of study material and a number have come personally to examine the collections. Besides these there have been many inquiries from various correspondents.

An important addition to the museum activities was the making up and loaning of elementary study collections to the Ottawa public schools. The schools furnished specimen boxes of convenient size and form. These sets are distributed amongst the various schools where they remain for a definite period after which they are removed to the next school according to a fixed programme. Thus

in the course of the year each school will have had each case for a period long enough to study its contents. This work was inaugurated last year. At the end of the school year all the cases were returned, the specimens were repaired, replaced, and rearranged, according to a more definite system and again distributed for the present season. Each box as now arranged is calculated to illustrate some definite subject as follows.

Box 1. Winter Birds. A collection of thirteen species of birds that might be seen any winter's day in or about the city; also examples of common winter birds' food such as Rowan berries, Manitoba maple seeds, etc.

Box 2. Birds' Nests. Six nests in situ showing as great a variety in situation, material, technique, etc., as possible.

Box 3. Birds of Garden and Roadside. Twelve birds of species that come familiarly about the house.

Box 4. Teeth of Animals. Examples of flesh and insect eating animals and rodents with cleaned and mounted skulls, calling attention to the relation of dentition to food habits.

Box 5. Common Birds Every One Should Know. A collection of twenty-two common birds that should be familiar to everybody; also a small case showing the differences between moths and butterflies and the principal facts of their development.

Box 6. Means of Protection. Examples of protective devices used by various animals:

Red Squirrel	Speed and agility.
Ruffed Grouse	Protective coloration.
Skunk	Strong protective odour.
Porcupine	Sharp spiny covering.
Mud Turtle	Hard protective covering.

Also a small case illustrating and explaining mimicry, illustrated by the Monarch and the Viceroy butterflies, bees, wasps, flies, etc.

Box 7. Protective Coloration. Ruffed Grouse, Short-eared Owl, Meadow Lark, and Cotton-tail Rabbit, showing how closely some animals resemble their surroundings; also a small case showing Whip-poor-will amongst dead leaves and a white Weasel in the snow.

Box 8. Adaptations. Shows adaptations between form and habits illustrated by Sharp-shinned Hawk, and Shrike as rapacious birds; Goldfinch as a seed-eater; Buffle-head Duck as a swimmer; Pileated Woodpecker as a woodhewer; Muskrat as a swimming animal; and Short-eared Owl as a nocturnal bird.

Box 9. Woodpeckers. A collection of most of the common woodpeckers of the Ottawa district with a small case furnished with natural and artificial details showing the characteristics of the picerine form.

Boxes 10 and 11. Bird Classification. Two collections illustrating typical examples of each family of common birds and calling attention to their characteristics; also a small case of batrachians illustrating their development from tadpoles and the differences between frogs and toads.

These school collections have been in the nature of an experiment to see what can be done in this field of educative work and how far it is practicable to go in supplying specimens to public schools. The Ottawa schools were taken on account of their proximity and the specimens used were only such as could be spared or could be prepared without great expense. The problem of the permanency of such collections is the critical one. To make them specially for the pur-

pose is a matter of considerable expense and unless they last for a number of years it is doubtful whether they can be extensively used in schools distant from larger museums where a certain number of duplicate or other extra specimens are usually available and where there is an expert staff to repair and replace them. The condition, however, of those specimens that have already undergone a season's use is promising; and it is hoped that by special preparation and a larger use of indestructible casts such collections can be finally made economically practical. The collections have proved a success in the opinion of both instructors and pupils and the continuation of the experiment seems warranted.

The moving pictures of living birds, made by the staff last year, have been shown a number of times before both scientific and popular gatherings. The enthusiasm they have aroused is an indication of the great value of such work in both science and education. At present we have no lecture room of our own in which to show such pictures but they are available for loan to responsible educative bodies.

The zoological lantern-slide collection has also been in demand both by members of our own staff and by scientific and educational bodies in widely separate parts of the Dominion. It is believed that, were it generally known that we have lantern-slides for educational use, the demand would be considerably greater. For details of this work see page 10.

Accessions 1915-1916.

By the Staff of the Zoological Subdivision.

15–94. By preparatory staff—C. L. Patch, C. H. Young, and C. E. Johnson, near Ottawa, November, 1915.—
3 birds, skins and mounted.

15–100. By Canadian Arctic expedition—R. M. Anderson, Frits Johansen, and southern party, on Arctic coast from Coronation gulf westward. See 16-56 and preliminary report following.—
50 mammals, skins and skulls, catalogue Nos. 2547-2596.
78 bird skins, catalogue Nos. 8744-8821.
35 sets bird's eggs, catalogue Nos. 1111-1146.
—fish and invertebrates, not catalogued.

16–2. By zoological expedition—C. L. Patch, Barkley sound, Vancouver island, B.C., Jan.-Dec., 1915-16. See preliminary report following.—
21 mammals, skins, skeletons, and alcoholic specimens, catalogue Nos. 2599-2617 and 2921-2923.
118 bird skins, catalogue Nos. 8861-8978.
48 photographic negatives.
7 coloured plates of bird bills and feet.

16–14. By preparatory staff—D. J. Blakeley and C. L. Patch, near Ottawa, March, 1916.—
1 Red Squirrel, catalogue No. 2598.
4 Bird skins, catalogue Nos. 9038-9041.

16–29. By zoological expedition—C. H. Young, Douglas, Man., May 22-June 6, 1916. See preliminary report following.—
75 bird skins, catalogue Nos. 9067-9143.
24 photographic negatives.
6 sets bird's eggs, catalogue Nos. 1157-1159.

16–52. By zoological expedition with J. M. Macoun—C. H. Young and Wm. Spreadborough, Brackendale, Lillooet, and McGillivray creek, B.C., June 11-Sept. 12, 1916.—
116 mammal skins with skulls, catalogue Nos. 2627-2742.
444 bird skins, catalogue Nos. 9067-9143.
4 sets bird's eggs, catalogue Nos. 1170-1171.
50 photographic negatives.
—insects, spiders, etc., not catalogued.

16–56. By Canadian Arctic expedition—R. M. Anderson, Frits Johansen, and southern party on Arctic coast from Coronation gulf westward. See Accession above and preliminary report following.—
135 mammals, skins, skulls, legbones, and alcoholic specimens, catalogue Nos. 2743-2873 and 2917-2920.
334 birds, skins and alcoholic specimens, catalogue Nos. 9833-10166.
31 bird's eggs, catalogue Nos. 1192-1222.
—fishes, invertebrates, etc., not catalogued.
868 photographic negatives.

16–70. By preparatory staff—C. L. Patch, C. E. Johnson, and D. J. Blakeley near Ottawa, summer and autumn, 1916.—
18 mammals, skins, skulls, etc., catalogue Nos. 2899-2916.
99 birds, skins and mounted, catalogue Nos. 10255-10313.
20 sets bird's eggs, catalogue Nos. 1172-1191.
25 photographic negatives.
—reptiles, batracians, etc., not catalogued.

By Other Museum Divisions.

15–89. By division of vertebrate palæontology—Geo. Sternberg in the Red Deer River region, Alberta, summer, 1915.—
1 mammal, coyote, catalogue No. 2541.
18 birds, skins and alcoholic specimens, catalogue Nos. 8687-8704: Western Grebe, Mallard, Shoveller and Scaup ducks, Bittern, Sharp-shinned Hawk and Ferruginous Roughleg, Sharp-tail and Ruffed Grouse, Magpie, and Hairy Woodpecker.
2 snakes, catalogue Nos. 621-622.
21 fish, catalogue Nos. 1070-1090.

16–48. By division of vertebrate palæontology—Geo. Sternberg, near Morrin, Alberta, summer 1916.—
41 birds, skins, catalogue Nos. 9349-9365 and 9381-9387.
Black Tern, Rough-legged and Sparrow Hawks, Ruffed Grouse, Magpies, Meadow Lark, Flicker, Towhees, etc.
9 sets bird's eggs, catalogue Nos. 1161-1169.

16–51. By division of vertebrate palæontology—Geo. Sternberg, near Morrin, Alberta, summer 1916.—
12 birds, skins, catalogue Nos. 6369-6380.
Ferruginous Roughleg and Sparrow Hawk, Great Blue Heron, Sharp-tailed Grouse, Kingfisher, Magpies, Meadow Lark.

16–61. By division of vertebrate palæontology—Geo. Sternberg, near Morrin, Alberta, summer 1916.
22 mammals, alcoholic specimens, catalogue Nos. 2874-2895.
14 birds, skins, catalogue Nos. 10199-10212.
Horned and Holboel's Grebes, Hawk, Owl, Great Horned and Long-eared Owls, Pintail and Scaup ducks, Ruffed-Grouse, Kingfisher, and Crow.
1 reptile, catalogue No. 625.
347 fish, catalogue Nos. 1091-1189.

16–67. By transfer from mineralogical division.—
—molluscs, not catalogued.
A collection of foreign shells presented to Sir R. L. Borden by W. G. Rutherford, Bute Court, Torquay, Devon, England, and deposited in the Museum. Accession 2767 in mineralogical division records.

By Geological Staff.

15–92. By Robert Harvie.—
1 Muskrat, Cantley, Que., catalogue No. 2542.

15–95. By M. Y. Williams.—
2 Red Squirrels, Picton, Ont., catalogue Nos. 2543-2544.

15–98. By Robert Harvie.—
1 Red Squirrel, Carleton co., Ont., catalogue No. 2545.

16–7. By Robert Harvie.—
1 Ruffed Grouse, South Bolton, Que., catalogue No. 9015.

16–8. By W. J. Wright.—
1 set Woodcock eggs, Frederick brook, N.B., catalogue No. 1150.

16–21. By Robert Harvie.—
1 Savanna Sparrow, Ottawa, Ont., catalogue No. 9056.

16–23. By A. O. Hayes.—
1 Great Blue Heron, Bernard lake, Que., catalogue No. 9057.

16–33. By M. Y. Williams.—
1 Broad-winged Hawk, New Liskeard, Ont., June, catalogue No. 9156.

16-57. By Robert Harvie.—
1 Porcupine, Rideau Lake, Ont., catalogue No. 2924.
1 Pectoral Sandpiper, Ottawa, Oct., catalogue No. 10167.

16–58. By Chas. Drysdale.—
Pileated Woodpecker, B.C., catalogue No. 10168.

16–62. By D. D. Cairnes.—
—lepidotera, papered, and about twenty vials of insects, spiders, etc., in alcohol, near head of Klotassin and Selwyn rivers, Y.T., not catalogued.

16–63. By Robert Harvie.—
1 Redpoll, Ottawa, Nov., catalogue No. 10213.

By Presentation.

15–90. By J. P. Williams, Picton, Ont.—
1 Red-tailed Hawk, Picton, Nov., 1915, catalogue No. 8705.

15–93. By Mr. Garland, Russell, Ont.—
1 Goshawk, Russell, Ont., catalogue No. 8822.

15–99. By Mr. Geo. A. Moore, Carp, Ont.—
1 Black-squirrel, Carp, Ont., catalogue No. 2546.

16– 1. By anonymous, Ottawa, Ont.—
1 Evening Grosbeak, Ottawa, Jan., catalogue No. 8860.

16– 4. By Dominion Parks Branch.—
1 Mounted Wild Turkey, originally presented by Geological Survey to Rocky Mountain Park Museum at Banff. Probably a Canadian record.

16– 6. By Mr. H. Mousley, Hatley, Que.—
1 nest American Goldfinch, Hatley, Que., catalogue No. 1151.

16–10. By Mr. E. W. Garland, Richmond, Ont.—
1 Evening Grosbeak, Richmond, Ont., Feb., catalogue No. 9022.

16–12. By Mr. H. Mousley, Hatley, Que.—
1 Evening Grosbeak, Hatley, Que., March, catalogue No. 9031.

16–15. By Mr. C. W. Garland, Richmond, Ont.—
2 Evening Grosbeaks, Richmond, March, catalogue Nos. 9042–9043.

16–17. By Miss Lees, Riverdale ave., Ottawa, Ont.—
1 Evening Grosbeak, Ottawa, Ont., catalogue No. 9044.

16–18. By Mr. Thos. Hamilton, Brinston, Ont.—
1 Florida Gallinule, Brinston, April, catalogue No. 9055.

16–19. By Mr. John Rowley, San Francisco, Cal.—
17 photographs of Sea-lions.

16–20. By Mr. Gordon Watson, 172 Cartier street, Ottawa, Ont.—
125 (about) eggs (singles) of various species of birds, and skull of European Curlew, not catalogued.

16–22. By Mr. J. C. Carleton, Quarries, Que., near Ottawa.—
1 Ground-hog, near Ottawa, May, catalogue No. 2618.

16–24. By anonymous. Mailed from Ile aux Noir, Que., May 20.—
1 Caspian Tern in flesh, catalogue No. 9058.

16–25. By Mr. Eardley Young, Ottawa, Ont.—
1 nest and 5 eggs of Water Thrush, Meach Lake, Que., near Ottawa, catalogue No. 1156.

16–26. By Wm. Bodin, Wilson point, Miscou island, N.B.—
2 bird skins, White-winged Scoter and Fish Hawk, Miscou island, catalogue Nos. 9059–9060.

16–31. By anonymous.—
1 Purple Martin, Ottawa, catalogue No. 9152.

16–32. By Mr. F. C. Hennessey, Ottawa, Ont.—
3 Henslow's Sparrows, Albion, Mich., catalogue Nos. 9153–9155.

16–35. By Mr. Delvida Poirier, Valleyfield, Que.—
1 Harvest Fly, not catalogued.

16–36. By Mr. G. S. Hume, New Liskeard, Ont.—
1 Luna Moth, not catalogued.

16–37. By Mr. Dewy Soper, Preston, Ont.—
1 Savanna Sparrow skin, Preston, Ont., catalogue No. 9184.

16–38. By Mr. H. Mousley, Hatley, Que.—
1 nest in situ of Black-throated Blue Warbler, Hatley, Que., July 1916, catalogue No. 1160.

16–39. By Mr. Dewy Soper, Preston, Ont.—
1 Snapping Turtle, Preston, Ont., catalogue No. 624.

16–41. By Brother Secordian, Notre Dame College, Hull, Que.—
1 Harvest Fly, not catalogued.

16–44. By M. Y. Williams, Geological Survey, Ottawa, Ont.—
Weathered antlers of White-tailed Deer, picked up near Picton, Ont., showing the form of antler of the deer once native to Prince Edward co., Ont., but now extinct there, catalogue No. 2619.

16–45. By Brother Secordian, Notre Dame College, Hull, Que.—
1 Salamander, Hull, Que., not catalogued.

16–47. By Mr. W. Taylor, 2301 Trinity st., Vancouver, B.C.—
1 Dipper, Garibaldi meadows, B.C., catalogue No. 9366.

16–49. By Mrs. P. E. Rickard, 56 Wilbrod St., Ottawa, Ont.—
1 large spider found in banana shipment, not catalogued.

16–50. By Mr. H. Mousley, Hatley, Que.—
2 birds, White-winged Crossbill and Cape May Warbler, Hatley, Que., late August, catalogue Nos. 9367–9368.

16–54. By Mr. E. N. Halton Fyles, Frederick House, Ont.—
1 Goshawk, Cochrane, Ont., Sept., catalogue No. 9832.

16–55. By Mr. J. A. Salter, St. Nicholas, Que.—
1 Centipede, *spirobolus marginatus*, not catalogued.

16-60. By Mr. W. E. Saunders, London, Ont.—
Small collection of land shells and small clams, not catalogued.

16-64. By Mr. Anstruther Mainguey, 188 Cooper st., Ottawa.—
1 Brown Bat, Ottawa, catalogue No. 2896.

16-65. By Mr. E. W. Garland, Richmond, Ont.—
1 Goshawk, Richmond, Ont., Nov., catalogue No. 10214.

16-68. By Mr. J. A. Munro, Okanagan Landing, B.C.—
31 lots fish, not catalogued.
21 lots reptiles and amphibians, not catalogued.
1 crustacean, not catalogued.
3 insects (?) larvae, not catalogued.
81 vials of various native seeds.
All collected in Ontario, mostly near Toronto, except three lots of reptiles from the island of Malta.

16-69. By A. H. Shouldis, Ottawa, Ont.—
1 White-tailed deer, skin and skull, catalogue No. 2898.

16-71. By Edward Kinsella, Franktown, Ont.—
1 Star-nosed Mole, Franktown, Dec., catalogue No.

16-72. By Dominion Parks Branch.—
1 Black Bear skull, Banff park, Alberta, catalogue No.

16-73. By Nicholas Pankiw (?), Teulon, Man.—
1 Lapland Longspur, Teulon, Man., catalogue No. 10314.

16-74. By Mr. Ed. G. White, Ottawa, Ont.—
2 Shoveller ducks, Findlay, Man., catalogue Nos. 10316, 10317.

16-75. By T. B. Williams, Canmore, Alberta.—
1 small weasel taken in coal mine, Canmore, catalogue No.

16-76. By P. I. Bryce, Ste. Anne de Bellevue, Que.—
1 Brown Bat, Ste. Anne de Bellevue, catalogue No.

By Exchange.

15-97. With Mr. Edwin Arnold, Montreal, Que.—
4 bird skins—2 Kirtland's Warbler, 2 Black Rails, catalogue Nos. 8826-8829.
3 sets eggs–Kirtland's Warbler, Black Rail, and Lesser Yellow-legs, catalogue Nos. 1147-1149.

16- 5. With A. C. Bent, Taunton, Mass.—
8 bird skins—Least and Roseate Terns, Pacific Godwit, and Sooty Shearwater, catalogue Nos. 9007-9014.

16–16. With Mr. Edwin Arnold, Montreal, Que.—
4 sets bird's eggs—Everglade Kite, Prairie Falcon, Parula Warbler, and Black-necked Stilt. The latter taken near Ft. Qu'Appelle, Sask., June 13, 1894, forming the only Canadian breeding record of the species, catalogue Nos. 1152–1155.

16–28. With J. H. Fleming, 267 Rusholm road, Toronto, Ont.—
4 bird skins—2 Black and 2 Yellow Rails, catalogue Nos. 9063–9066.

16–30. With Dr. Jonathan Dwight, New York.—
9 bird skins—Eared Grebe; Cassin's and Crested Auklets; Royal, Forster's, and Least Terns, and Pelagic Cormorant, catalogue Nos. 9143–9151.

16–40. With New York State Museum, Albany, N.Y.—
11 bird skins—Caspian, Royal Sooty, Cabots, and Gull-billed Terns; Laughing and Mew Gulls; Allied Shearwater; Bulwer's Petrel, and Anhinga, catalogue Nos. 9185–9195.

16–42. With Dr. L. B. Bishop, New Haven, Conn.—
10 Greater Shearwaters, near Halifax, N.S., Aug., catalogue Nos. 9196–9205.

16–77. With Ward's Natural Science Establishment, Rochester, N.Y.—
1 Aleutian Tern, catalogue No. 9188.

By Purchase.

15–88. From Mr. Chas. Horsbrough, Red Deer, Alberta.—
35 bird skins—Western, Eared, Holboell's, and Horned Grebes; Blue-winged Teal, Canvas-back, Scaup, Pintail, White-winged Scoter, and Bufflehead ducks; Black Tern and Franklin's Gull; Ross' Goose; Long-eared, Short-eared, Saw-whet, and Hawk Owls; Sharp-shinned, Goshawk, and Swainsons Hawks; Killdeer; Crow; Hairy Woodpecker; Bronzed and Rusty Grackles. All from Alix and Buffalo lake, Alberta, catalogue Nos. 8706–8740.

15–96. From Wm. Bodin, Wilson point, Miscou island, N.B.—
19 bird skins—Herring, Ring-billed, and Black-backed gulls; Gannet; Red-breasted Merganser; Pintail, Goldeneye, and Eider ducks; White-rumped and Pectoral Sandpipers; Black-bellied and Semi-palmated Plover; Fox Sparrow; Black-poll and Magnolia Warblers; Hermit Thrush. Taken Miscou island, Oct., catalogue Nos. 8830–8848.

15–101. From Wm. Duvall, Bonaventure island, Gaspe co., Que.—
6 Dovekies, Percé, Que., catalogue Nos. 8849–8854.

16–3. From Wm. Bodin, Wilson point, Miscou island, N.B.—
26 bird skins—Red-throated Loons; Brunnich's Murre; Black Guillemots ;Kumlein's, Iceland, Herring, and Black-backed gulls; Black, Barrow's Goldeneye, and Eider ducks; Snow Buntings; White-winged Crossbills, and House Sparrows, catalogue Nos. 8979–9005.

16–9. From Wm. Duvall, Bonaventure island, Gaspe co., Que.—
6 birds, Purple Sandpipers and Barrow's Goldeneyes, catalogue Nos. 9016–9021.

16–11. From Wm. Duvall, Bonaventure island, Gaspe co., Que.—
5 birds—Eiders, Barrow's Goldeneyes, and Scaup Duck, catalogue Nos. 9023–9030.

16–13. From Wm. Duvall, Bonaventure island, Gaspe co., Que.—
5 birds—Barrow's Goldeneyes and Scaup Duck, catalogue Nos. 9033–9037.

16–27. From Mrs. Sam Cox, Harrington Harbour, Saguenay co., Que. (Canadian Labrador).—
2 birds—Black Guillemots, catalogue Nos. 9061–9062.

16–34. From Charlie Ross, Barkley sound, Vancouver island, B.C.—
27 birds—Surf birds and Black Turnstone, Barkley sound, May. Made into skins and alcoholic specimens, catalogue Nos. 9157–9183.

16–43. From John Goddard, Stick point, near Bonne Esperance, Saguenay co., Que. (Canadian Labrador).—
17 bird skins—Red-throated Loon, Black Guillemots, Herring Gulls, Barrow's Goldeneye, White-winged Scoter, Eiders, Rough-legged Hawk, Richardson's Owl, Willow-Ptarmigan, Spruce Partridge, and Raven. All from near Bonne Esperance, catalogue Nos. 9206–9221.

16–46. From M. Y. Williams, Geological Survey, Ottawa, Ont.—
7 mammals, catalogue Nos. 2620–2626.
125 bird skins, catalogue Nos. 9223–9348. Mostly taken in Prince Edward co., and all previous to the collector's appointment on the Survey staff.

1 –59. From Mr. John Goddard, Stick point, near Bonne Esperance, Saguenay co., Que. (Canadian Labrador).—
30 bird skins—Pied-billed Grebe, Black Guillemots, Kittiwake, Black-backed and Herring gulls, Puffins, Sooty Shearwater, Wilson's Petrel, Red-breasted Merganser, Surf Scoter, Yellow-legs, Purple Sandpipers, Black-bellied plover, Spruce Partridges, Willow Ptarmigan, catalogue Nos. 10169–10198.

16–66. From Wm. Stauffer, Morrin, Alberta.—
1 Lynx skin without skull, catalogue No. 2897.

Reconnaissance in Barkley Sound, on the West Coast of Vancouver Island.

(*Clyde L. Patch.*)

The Provincial Government of British Columbia decided to investigate the feeding habits of Steller's Sea-lion, for the purpose of ascertaining whether or not they destroyed food fish and fishing nets. C. F. Newcombe, M.D., chairman of the investigating committee, offered the Museum the specimens killed for examin-

ation, provided the institution send a representative to prepare the hides and skeletons for shipment.

Having received word early in December that sea-lions were plentiful in Barkley sound, Dr. Newcombe notified the Museum and I joined him in Victoria. Two days later we arrived at Port Alberni and the following morning, December 16, we proceeded through the Alberni canal to the Kildonan salmon cannery. During our three weeks stay there we were generously accommodated by Mr. Martin, manager, and his men. We saw five solitary sea-lions while passing through the canal.

Having obtained a special permit from Mr. Francis Kermode, director of the British Columbia Provincial Museum, I immediately began collecting ornithological specimens, while Dr. Newcombe arranged to procure sea-lions from the Nootka Indians by offering $7.50 for specimens delivered alongside the float. He also arranged a personally supervised hunt in a motor boat, which gave us an opportunity to observe and photograph the hunting Indians.

During the winter months the sea-lions move about singly or in herds numbering up to forty individuals, spending only a small part of their time on the rocky islands, to the vicinity of which they return each autumn from their breeding grounds. Before the advent of the rifle the Indians obtained sea-lions by harpooning; but, now that the sea-lions have become much more wary, the hunters first shoot them as they raise their heads above the water's surface to breathe, and then if the wound is not fatal, they rush in and harpoon them. If instantly killed by the rifle shot they sink before the harpoon can be thrown. Less than 25 per cent of the specimens shot are procured. Sea-lion meat, which tastes like beef that has been boiled in water previously used for cooking fish, is eaten by the Indians, also the heart and liver. The hides are used for covering boats and the soles of the flippers for moccasin soles.

Three bull sea-lions were procured by our hunting party and eight bulls and one cow were purchased by Dr. Newcombe, who considered these twelve specimens sufficient for his investigation. I later purchased two cows. The greater number of bulls procured can be accounted for by the fact that an adult cow weighed 652 pounds, while a bull may weigh up to 2,100 pounds, their heads, therefore, affording a much larger target. Each of the three cows contained a single foetus measuring $12\frac{3}{4}$, $12\frac{3}{4}$, $13\frac{3}{4}$ inches from tip of nose to tip of tail. Of the fourteen stomachs four contained rounded biotite-granite rocks weighing approximately 1 pound 3 ounces and measuring about $8\frac{1}{2}$ inches in circumference. One stomach contained two such rocks, the other three one each. When and why these rocks are swallowed by the sea-lions is unknown. Possibly they in some way affect the hair-like worms that adhere in varying quantities to the majority of the stomach linings; but probably they are unintentionally swallowed along with the molluscan food and sea-weed which adhere to them.

Besides procuring the fourteen sea-lion hides and skeletons I made a series of plaster casts of heads, and fore and back flippers, of cows, juvenile bulls, and of an adult bull, which will be used as studies in modelling an exhibition group of sea-lions.

Leaving Kildonan on January 4 and accompanied by three Indians I made a three days cruise through Namint bay, Uchucklesit harbour, Effingham inlet, and among the islands of Barkley sound, collecting thirty-seven species of birds, two raccoons, one harbour seal, and two deer. The collection of birds includes specimens of all varieties observed, with the exception of the Coot. Fifty-eight per cent of the birds collected in Namint bay and Uchucklesit harbour, the two most inland bays of Barkley sound, were females or juveniles; in more exposed Effingham inlet and among the islands only twenty-eight per cent were females and juveniles, the balance being adult males.

About the cannery were hundreds of gulls and crows which are very bold, approaching within a few feet of the workmen and frequently entering the hold of a fish-laden boat and gorging themselves with herring until unable to fly out. The adult gulls about the cannery were far outnumbered by juvenile birds, which fact accounts for the predominance of adult birds seen following coasting vessels; birds of the year evidently prefer a quiet life near shore to the strenuous existence at sea.

Ducks were feeding on putrid salmon bodies that had drifted to the mouths or sunken in the deeper parts of the freshwater streams up which the fish had spawned and died.

On January 4, on rocky Bird island and adjacent barren rock islands, I saw three compact flocks of Surf-birds each probably numbering two or three hundred individuals. One charge from a twelve-gauge shot gun brought down twelve Surf-birds and two Purple Sandpipers. There were undoubtedly a considerable number of Sandpipers accompanying the Surf-birds, but owing to the heavy sea about the rocks it was impossible to closely observe the flocks or to retrieve more dead birds. The Surf-birds, whose breeding ground has never been discovered, were of particular interest as heretofore they have been known to winter only on the South American coast.

Only six Harbour seals were seen, all of which were in the water. The Black-tail Deer were collected on small islands in Barkley sound. The Indians say they are fairly common. The doe, which was about two years old judging by the teeth, measured 1,400 mm. and the three year old buck 1,580 mm.

Preliminary List of Specimens Taken by C. L. Patch, Near Barkley Sound, Vancouver Island, Between December 16, 1915, and January 1, 1916.

(*P. A. Taverner.*)

Accession 16–2.

1. Holbœll's Grebe, *Colymbus holbœlli.*
   ♂ ♂ ♀ jvs.

2. Horned Grebe, *Colymbus auritus.*
   ♀ ♀ jvs.

3. Pied-billed Grebe, *Podilymbus podiceps.*
   ♂ jv.

4. Pacific Loon, *Gavia Pacifica.*
   ♂ ♂ jvs.

5. Red-throated Loon, *Gavia stellata.*
   ♀ jv.

6. Marbled Murrelet, *Brachyramphus marmoratus.*
   ♂ ♂ ♂ ♂ all in white winter plumage.

7. Common Murre, *Uria troille.*
   ♀ ♀ ♀ ♀ ♀ all referable to the subspecies *californica.*

8. Glaucus-winged Gull, *Larus glaucescens.*
   ♀ ad. ♂ jv.

9. Herring Gull, *Larus argentatus.*
♀ ♀ jv. ♀ ? These birds belong to the form newly described (Brooks, Bull. Mus. Comp. Zool., vol. LIX, No. 5, pp. 361–413) as *Larus thayeri*, which appears to be a subspecies of *argentatus* and the Pacific Coast representative of that species.

10. Short-billed Gull, *Larus brachyrhynchus.*
♀ ♀ ♀ jv. ♀ jv. (?).

11. Double-crested Cormorant, *Phalcrocorax auritus.*
♀ ♂ both referable to the subspecies *cincinnatus.*

12. Brandt's Cormorant, *Phalcrocorax penicillatus.*
♂ ♀ ♀.

13. Pelagic Cormorant, *Phalcrocorax pelagicus.*
(sex. ?) referable to the subspecies *robustus.*

14. American Merganser, *Mergus americanus.*
♂ ♂ jv.

15. Hooded Merganser, *Lophodytes cucullatus.*
♂ jv.

16. Mallard, *Anas platyrhynchos.*
♀.

17. Greater Scaup, *Marila marila.*
♂ ad.

18. Goldeneye, *Clangula clangula.*
♂ ♂ ♂ jv. ♂ jv. ♀.

19. Barrow's Goldeneye, *Clangula islandica.*
♂ ♂ ♂ ♂ ♂ ♂ ♂ jv. ♂ jv.

20. Bufflehead, *Charitonetta albeela.*
♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ jv. ♀ ♀.

21. Harlequin Duck, *Histrionicus histrionicus.*
♂ ♀.

22. American Scoter, *Oidemia americana.*
♂.

23. White-winged Scoter, *Oidemia deglandi.*
♂ ♂ ♂ ♀ ? ♀ ? (?).

24. Surf Scoter, *Oidemia perspicillata.*
♂ ♂ ♂ ♂ ♀ ♀ (?) (?).

25. Purple Sandpiper, *Arquatella maritima.*
♂ ♂. The exact subspecies of these birds cannot be decided without a larger series of determined specimens for comparison. They differ from eastern birds in comparable plumage in being more sharply streaked below and on throat, otherwise they are nearly if not quite identical with them. It is questionable whether they should be referred to the subspecies *couesi* or *ptilocnemis.* May birds taken at Ucluelet, Vancouver island, in our collection have been determined as the former.

26. Surf-bird, *Aphriza virgata.*
♂ ♂ ♂ ♂ ♀ ♀ ♀ ♀ ♀ ♀ ? (?) (?). These were taken at a single shot on some of the rocky islets out in the sound, that are seldom visited by white men in the winter time. There were large numbers present so these cannot be regarded as accidental stragglers. The occurrence of this species in this latitude as late as January 4 was something of a surprise.

27. Black Turnstone, *Arenaria melanocephala.*
♂ ♀ (?).

28. Black Oyster-catcher, *Hæmatopus bachmani.*
♂.

29. Bald Eagle, *Haliæetus leucocephalus.*
♂ jv. ♂ nearly adult.

30. Belted Kingfisher, *Ceryle alcyon.*
♀. I cannot see that the western form *caurinus* is subspecifically distinct from eastern birds.

31. Red-breasted Sapsucker, *Sphyrapicus ruber.*
(?) Identified geographically as *notkensis.*

32. Northwestern Crow, *Corvus caurinus.*
♂ ♀ (?).

33. Song Sparrow, *Melospiza melodia.*
♂ ? ♂ ? (?). If *morphna* is untenable as has been said these specimens must be regarded as the subspecies *rufina.*

34. Fox Sparrow, *passerella iliaca.*
(?) This specimen is well marked *fulignosa.*

35. Dipper, *Cinclus mexicanus.*
(?)

36. Winter Wren, *Nannus hiemalis.*
♀ ?. Identified geographically as *pacificus.*

37. Varied Thrush, *Ixoreus nævius.*
♂ ♂ ♀ (?).

British Columbia Field Work.

(*C. H. Young.*)

The writer, accompanied by Wm. Spreadborough, spent the period June 9 to 30 (1916) collecting zoological specimens in the vicinity of Brackendale on the Pacific Great Eastern railway a few miles from Howe sound, and on Squamish river. Brackendale had also been selected by J. M. Macoun as a suitable place for his botanical work. It proved an excellent locality for bird collecting. Much of the country west of our camp was under cultivation, while eastward very little has been cleared although much of it has been burnt over. While there we collected 153 skins of birds and 33 mammals. All the mammals and practically all the birds were collected below an altitude of 100 feet and all may be considered as resident coast species, as the migration season was about over when we reached Brackendale. The number of resident individual birds was not very large at Brackendale as was shown both by our own observations and by the fact that many species were represented by only one or two pairs. Several thousands of acres of brulé offered an apparently fine field for woodpeckers, but nearly every individual seen was shot.

The period July 1 to August 8 was spent at Lillooet. A few trips were made into the hills from this point but nearly all the specimens taken were collected within a mile or two of camp at altitudes between 700 and 1,500 feet above the sea, the altitude of Lillooet station being 740 feet. Our camp was near the discharge of Seton lake, with the Cascade mountains to the west of us, but our hunting ground was chiefly in the Fraser valley a mile or so eastward. Lillooet is situated on the western edge of the "dry belt" and sage-brush and cactus are found everywhere in the valley; so that while the collection includes many coast species there are many others that are characteristic of the dry interior. Nearly all the mammals were taken quite near camp. As there is a very old settlement at Lillooet, as well as several Indian reserves in the immediate vicinity, this also proved to be a good collecting ground and most of the species known to occur in the region were taken, as well as several species that had not before been recorded. It may be of interest to note that we were told by an old resident that the Evening Grosbeak which we found to be fairly abundant had only become so since the planting of the Ash-leaved Maple in the streets of Lillooet some twenty-five years ago, these birds feeding in winter on the fruit of this tree. Mount McLean within easy reach of Lillooet affords an excellent collecting ground for alpine species, but as our intention was to camp later in a similar locality farther west only two or three trips were made to this mountain.

We left Lillooet August 8 and spent the next two weeks at the forks of McGillivray creek with our camp at an altitude of 4,500 feet. Few, if any, of the specimens collected were from an altitude lower than our camp as we had a dense forest below us while above us much of the country was open. Trails lead up both branches of McGillivray creek and the mountains although high were easily ascended up to the sources of both branches . Most of the small mammals were taken quite close to the main camp; the elevations of the remainder are indicated in the list following.

Returning to Lillooet August 23 a few days were spent there packing up our collections. On August 26 we returned to Brackendale where we camped until September 12 adding quite a number of species to our June list, some of them being evidently migrants.

Preliminary List of Specimens Taken by C. H. Young and Wm. Spreadborough, at Brackendale, Lillooet, and McGillivray Creek, British Columbia, Between June 11 and September 12, 1916.

(*P. A. Taverner.*)

Accession 16-52.

1. Least Sandpiper, *Pisobia minutilla.*
♂ jv., ♀ jv., Brackendale, Sept. 7.

2. Western Sandpiper, *Ereunetes mauri.*
♀, Brackendale, Sept. 7. Not as strikingly red as spring *mauri* but considerably redder than comparable eastern *pusillus.*

3. Solitary Sandpiper, *Helodromas solitarius.*
♂, Brackendale, August 28. Though by geography this specimen should undoubtedly be *cinnamomeus* it exhibits none of the characters of that subspecies. The back spots are white and there is no marbling on the primary webs. Identified by geography this should be *cinnamomeus,* by character, typical *solitarius.*

4. Greater Yellow-legs, *Totanus melanoleucus.*
♂, Brackendale, Sept. 2.

5. Spotted Sandpiper, *Actitis macularia.*
♂, Brackendale, ♂ ♂ ♂, 3 downy young, Lillooet.

6. Dusky Grouse, *Dendragopus obscurus.*
♀ ♀ ♀ ♀, ♀ ♀ half grown, 1 chick, Lillooet. Of the recognized forms of Dusky Grouse these are clearly referable to *fulignosus.* Comparing females, three Vancouver Island birds are the reddest in our collection. Three from the head of Howe sound (previous collecting) are a richer and darker brown on back. The Lillooet birds are considerably greyer on the back than either. The under parts are also a little less blue than those from other localities but not markedly so. The distinction, however, is too small for subspecific recognition. The small chick, just flying, is quite comparable in age, though a little older, with two Comox specimens, but the latter are decidedly red while the former is quite slaty and shows little reddish though the pronounced juvenile back pattern with numerous white shaft lines is similar, indicating the comparability of plumage.

7. Ruffed Grouse, *Bonasa umbellus.*
♀, ♂ ? downy young, Brackendale, June 9, adult in red phase. The whole back is markedly richer than that of interior birds, with only slight indications of grey overwash on feather tips. The breast is also redder with more sharply defined markings and blotches. The Vancouver Island and adjoining coast form, including this specimen, is clearly referable to *sabini.*

8. White-tailed Ptarmigan, *Lagopus leucurus.*
♂ ♂ ♀ ♀, McGillivray creek, altitude 8,500-8,600 feet, August 19. In full summer plumage. The males agree very closely with a fragmentary skin from Teslin Lake region, but the females have much less reddish, brown, or ochre than is shown in specimens from Teslin lake, Mt. Natazhof, Y.T., or Griffin lake, B.C. This difference is probably individual rather than subspecific and the specimens are referred geographically to the type form.

9. Band-tailed Pigeon, *Columba fasciata.*
♀, Brackendale, June 16, by geography, the typical form.

10. Mourning Dove, *Zenaidura macroura.*
♀, Brackendale, August 28. A small bird too juvenile (?) to base subspecific determination upon.

11. Sharp-shinned Hawk, *Accipiter velox.*
♂ ♂ ♀ ♀ ♀, Brackendale, June 6, and Sept. 6-7; Lillooet, Aug. 4.

12. Goshawk, *Astur atricapillus.*
♂ jv., Sept. 25, ♂ June 25; ♂ going into adult plumage, July 13, ♀ jv., Aug. 4.
While British Columbia birds do seem to average a little more blue on the back and have stronger dark edgings to the inter-scapulars they are indistinguishable from many eastern ones. The fineness of the breast vermiculations seems to be more an indication of age than geography; younger birds being more coarsely marked than old ones. I refer these to the type form.

13. Pigeon Hawk, *Falco columbarius.*
♂ jv., Lillooet, Aug. 3, Typical *columbarius.*

14. Sparrow Hawk, *Falco sparverius.*
♂ ♂ ♀ ♀, Brackendale, June 10-19, and Aug. 29; ♀ ♀ Lillooet, July 19; McGillivray creek, Aug. 11.
I cannot see that these or any other Canadian specimens differ more than individually from eastern birds. I include them, therefore, under the typical form.

15. Great Horned Owl, *Bubo virgianus.*
♀ ♀, Lillooet; ♂ downy young, Brackendale.
The two adult Lillooet birds agree closely with specimens identified by H. C. Oberholser as *lagophonus.* They are much less ocheraceous and quite distinct from our only *saturatus* as determined by the same authority. We have not material for judging the wisdom of the separation of these two forms. If both forms are valid these birds should be referred to the interior form *lagophonus* rather than the coast one, *saturatus.* The Brackendale bird is too young for subspecific recognition.

16. Belted Kingfisher, *Ceryle alcyon.*
♂ ♂, Brackendale, ♀ ♀ Lillooet.
While these birds can be regarded as showing the long secondaries of *caurina* we have so many Vancouver Island and adjoining coast birds that show extreme eastern characters that I cannot recognize the validity of the western subspecies. Our specimens indicate that while eastern ones never or rarely show extreme western characters, western ones often show characteristic eastern measurements. This does not seem sufficient basis for subspecific recognition.

17. Hairy Woodpecker, *Dryobates villosus.*
♂ ♂ ♂ ♀ ♀, Brackendale; ♂ Lillooet.
These birds may be divided three and three, ♀ ♀ Brackendale and ♂ jv. Lillooet are straight *monticola* and, while much soiled below have no evident smokiness. The remaining Brackendale birds, slightly smoky below, are *harrisi* tending towards *monticola*, one specimen being quite intermediate.

18. Downy Woodpecker, *Dryobates pubescens.*
♂ ♀, Brackendale; ♂ Lillooet. All birds of the year.
The two Brackendale birds are fairly well tinged with the smoky drab of *gairdneri* below. The Lillooet specimen is considerably lighter, generally white below with a tinge of darker in the middle of the breast. I regard it as intermediate between *gairdneri* and *homorus*.

19. American Three-toed Woodpecker, *Picoides americanus.*
♀, Lillooet. This bird does not agree strikingly with descriptions and we have no series of eastern birds for comparison. I regard it on geographical evidence as *fasciatus*.

20. Yellow-bellied sapsucker, *Sphyrapicus varius.*
♂, ♀ jv. ♀ jv., Lillooet, July 11–19.
All well marked *nuchalis*.

21. Red-breasted Sapsucker, *Sphyrapicus ruber.*
♂ ♂ ♀ ♀, ♀ jv., Brackendale, June 14–27 and Aug. 28, ♂ Lillooet, Sept. 5. Not having series of the southern form for comparison I refer these to *notkensis* geographically.

22. Pileated Woodpecker, *Phlœotomus pileatus.*
♂ ♂ ♀ ♀, Brackendale, June 12–20.
I can see little difference between east and west Canadian specimens. There may average slightly less white on the wing tips of western birds, but it is not constant and I see no good grounds for subspecific recognition of *picinus*. As between the northern and southern races of the species I refer these to *abieticola* geographically.

23. Lewis' Woodpecker, *Asyndesmus lewisi.*
♂ ♂ ♀ ♀, Brackendale, June 10 and Aug. 31–Sept. 2.

24. Red-shafted Flicker, *Colaptes cafer.*
♂, Brackendale, June 14.
A pure blood Red-shafted Flicker. Geographically it should be *saturatior* but is rather light coloured for that race and identical with many undoubted *cafer.*

24a. Hybrid Flicker, *Colaptes auritus cafer*·
♂ ♀ ♀ (all juveniles), Lillooet, July 25 and Aug. 5.

25. N'ght Hawk, *Chordeiles virginianus.*
♂ ♂ ♀, Brackendale, June 2–26; ♀ ♀ Lillooet and McGillivray creek, July 25 and Aug. 17.
These birds are slightly darker than birds from Trail, B.C., and Indian Head, Sask., that Mr. Oberholser has declared to be *hesperis,* and agree closely with eastern specimens. I, therefore, refer them to *virginianus* The Brackendale female is accompanied by an egg, so undoubtedly it is the breeding form of that locality.

26. Black Swift, *Cypseloides niger,*
♂ ♀ ♀ ♀, Brackendale, June 24–28.
Borealis by geography. I am informed by Mr. Young that the birds were evidently breeding in some numbers in high inaccessible cliffs.

27. Vaux's Swift, *Chaetura vauxi.*
♀ ♀, Brackendale, June 28.

28. Rufus Hummingbird, *Selasphorus rufus.*
♂, Brackendale, June 20; ♂, Lillooet, July 5.

29. Kingbird, *Tyrannus tyrannus.*
♂, Brackendale, June 24.

30. Arkansas Kingbird, *Tyrannus verticalis.*
♂, Brackendale, June 27. ♂ ♂, Lillooet, July 8 and 26.

31. Olive-sided Flycatcher, *Nuttallornis borealis.*
♂ ♂, Lillooet, July 11 and 13; alt. 4,000 feet.

32. Traill's Flycatcher, *Empidonax trailli.*
♂ ♂ ♂ jv., Brackendale, June 13-21, Aug. 30.
These show the greenish olive of *alnorum* and as such have been identified by Mr. Oberholser.

33. Hammond's Flycatcher, *Empidonax hammondi.*
♂ ♂, Brackendale, June 14, ♂ ♂ ♀ ♂ jv., Lillooet, July 13-19.
Identified as above by Mr. Oberholser.

43. Horned Lark. *Otocoris alpestris.*
♀ ♀, Lillooet, Aug. 1, ♂ ♀ ♀ ♀, McGillivray creek, Aug. 19.
All at elevation 7,000–7,500 ft.
These are large, light-coloured birds with yellows reduced to nearly pure white and only traces of vinaceous on wing coverts. The two adult Lillooet birds are badly worn and with backs sharply streaked. The remainder are birds of the year with streaks more soft and blended. I regard them provisionally as *arcticola* and probably local breeders.

44. Stellar's Jay, *Cyanocitta stelleri.*
♂ ♂ ♂ ♂ ♂ ♂ ♀, Brackendale, June 12–15; ♂, Anderson lake, Aug. 23. All are typical *stelleri.*

45. Canada Jay, *Perisoreus canadensis.*
These birds are in general coloration similar to *fumifrons* from Teslin Lake region, but have lighter breasts, a slight wash of brownish over-wash, and decided to faint shaft streaks on back. They appear to be *fumifrons* tending towards *obscurus*, thus suggesting that the latter should be reduced to subspecific rank. The white forehead is rather extensive and not sharply defined and in that direction might be regarded as approaching *capitalis.*

46. American Crow, *corvus brachyrhychos.*
♂, Brackendale, ♂ ♀, ♂ jv., Lillooet.
These all overmeasure *caurinus* and are, therefore, referred to *hesperis.*

47. Clarke's Nutcracker, *Nucifraga columbiana.*
♀, Lillooet, elevation, 6,000 feet, July 13, ♀ ♀, McGillivray creek, elevation, 5,000–6,000 feet, Aug. 11, 12.

48. Western Meadow Lark, *Sternella neglecta.*
♀ ♀, Brackendale, June 24, 26, ♂ ♂, Lillooet, July 31, Aug. 1.
In our collections, spring and early summer birds from British Columbia show consistently darker backs than is illustrated by our rather scanty series of prairie birds, thus substantiating the new subspecific form *confluenta* from northwestern Washington and British Columbia recently described by S. F. Rathbun, Auk, XXXIV, Jan. 1917, pp. 68–70. From the study of our own collections I previously suspected the existence of such a form but the examination of material in other collections failed to confirm the supposition in a convincing manner. Until a more careful re-examination can be made of material I hesitate to refer these birds to the new race.

49. Bullock's Oriole, *Icterus bullocki.*
♀, Lillooet, Aug. 1.

50. Brewer's Blackbird, *Euphagus cyanocephalus.*
♂ ♂ ♀ ♀, Brackendale, June 10–16.

51. Evening Grosbeak, *Hesperiphona vespertina.*
♂ ♂ ♂ ♂, ♀ ♀ ♀, ♂ jv. ♂ jv., Lillooet, July 3–Aug. 19.
The subspecific determinations of west Canadian Evening Grosbeaks is hardly satisfactorily determined. The western birds in our collection are certainly not as dark nor are the bills as attenuated as in typical *montana* as exhibited by birds from the Catalina mountains, Ariz., near the type locality. These birds agree so closely, allowing for seasonal variation, with eastern winter specimens that I cannot satisfy myself that they are anything more than the type form. No separate breeding ground for eastern birds has as yet been discovered; until it is, I hesitate to separate our eastern and western birds. Mr. Grinnell's revision of the species, Condor, XIX, 1917, 17-22, is founded upon such fine distinctions of bill shape that more convincing evidence than that before me is necessary for its acceptance. Until such evidence is obtained I can only refer these specimens to the type form.

52. Pine Grosbeak, *Pinicola enucleator.*

♂ ♀, Lillooet, July 11 and 19.

Though the various western races of this species are not very convincingly represented in our collections these birds seem to agree more nearly with *flammula* to which I refer them, but without strong conviction.

53. Purple Finch, *Carpodacus purpureus.*

♂ ♀, ♂ jv., Brackendale, June 8–16; ♀ ♀, ♂ ?, Lillooet, July 8–26.

Only the one Brackendale male is in red plumage, the remainder are all olive birds. They are typical *californicus.*

54. Grey-crowned Finch, *Leucosticte tephrocotis.*

♂ ♂ ♂ ♂ ♂ ♀, ♂ ♂ ♂ ♂ ♂ ♂ (juveniles) ♀ ♀ ♀ ♀ ♀ (juveniles).

These, judging from the adult specimens, are all well marked *littoralis.* The ear coverts are predominantly grey though with a slight tendency to be encroached upon by the brown. The throats are heavily mixed with brown. The juveniles are dull coloured, very similar in the neutral greyish undercolour to juvenile Cowbirds and with only suggestions of rosy on the feather edges of wings and coverts, more pronounced in females than in males.

55. American Goldfinch, *Astragalinus tristis.*

♂, ♂ jv., Brackendale; June 26 and Sept. 5, ♂ ♀, Lillooet, July 26–27.

Though falling within the measurements of the eastern form and not being perceptibly different in general colour from them the wing bars are pure white untinged with yellow and I assume that they are referable to *salicamans.*

56. Vesper Sparrow, *Pooecetes gramineus.*

♂ ♀ jv., (?) Lillooet, July 4–28.

These are typical *confinis.* I cannot refer them to *affinis* though geographically that might be expected.

57. Savannah Sparrow, *Passerculus sandwichensis.*

♂ ♂ ♂ ♀ ♀, ♀ ?, ♀ ?. Brackendale, Sept. 4–7.

Only two Savannah Sparrows were observed in June at Brackendale and they were common in September when these were taken. They are, therefore, probably early migrants, not residents. The subspecific status of the Savannah Sparrows of British Columbia, except perhaps those of the extreme southern border, does not seem to have been satisfactorily determined. They are usually referred to *alaudinus*, yet they differ radically from the diagnosis of that race as given by Mr. Ridgway. They are not greyer than eastern specimens but redder, vandyke rather than seal brown. The superciliary line is not less decidedly yellow but more so, chrome yellow rather than lemon yellow and diffuse rather than restricted. The wing lengths are identical with eastern birds though the bill is smaller and lighter. In fact except for a smaller bill spring birds are nearly indistinguishable from eastern autumn specimens. In autumn eastern and B. C. birds are separable with still greater difficulty. Western birds have backs slightly lighter brown and contrary to spring conditions the breast streaks are sharper and less diffuse than in eastern ones. These Brackendale specimens agree

perfectly with birds from the south Thompson and lower Fraser River valleys, with characters as above, and with them are temporarily referred to *alaudinus* until the form is renamed or the discrepancies of description explained.

58. White-crowned Sparrow, *Zonotrichia leucophrys.*
♂ jv. ♀ jv., Brackendale, Sept.
Being juveniles they are difficult of subspecific determination. They are slightly darker than comparable plains specimens and probably, therefore, *nutalli.* They are probably migrants.

59. Golden-crowned Sparrow, *Zonotrichic coronata.*
♀ jv., Brackendale, Sept. 7, ♂, Lillooet, July 26, ♂ ♂, McGillivray creek, altitude 6,000 feet, Aug. 14.

60. Chipping Sparrow, *Spizella passerina.*
♂ ♀, ♀ jv., Brackendale, June 10–27; ♂ ♂, Lillooet, July 6 and 26. These birds average a little larger and a little lighter than comparable eastern birds, but the difference is slight and they can be closely matched by occasional eastern specimens. I refer them to *arizonæ* but without conviction.

61. Oregon Junco, *Junco oregonus.*
♂ ♂ ♂ ♂ ♀ ♀ ♂ jv. ♀ jv., Brackendale, June 8–20, Sept. 7.
♂ ♂ ♂ ♀ ♀, Lillooet, July 4–25; ♂ ? jv., McGillivray creek, altitude 5,000 feet, Aug. 14.
According to the distribution of the A. O. U. check-list these should be *connectens*, but without a large series of well authenticated specimens it is difficult to subspecifically place the various Junco races. Dr. John Dwight is studying these specimens with others for what, it is to be hoped, will be a final decision upon this difficult group.

62. Song Sparrows, *Melospiza melodia.*
♂ ♂ ♂ ♂ jv. ♂ jv., June 10–16 and Sept. 6; ♂ ♂ ♂ ♂ jv., Lillooet, June 17–July 12.
If *morphna* is a synonym of *rufina* these should geographically be referred to the latter subspecies. Until after a thorough study of a series of determined specimens I prefer to leave open the subspecific status of these specimens.

63. Lincoln's Sparrow, *Melospiza lincolni.*
♂ ♂ ♀ ♀ ♀ ?, Brackendale, Aug. 31, Sept. 6. By date probably migrants. All are in new unworn plumage. In comparison with autumn birds from Ontario they are markedly olivaceous on the upper parts, hence I call them *striata*, though some doubt may well be expressed as to the tenability of that form.

64. Fox Sparrow, *Passerilla illiaca.*
♂ ♂ ♂ ♀, ♀ jv., McGillivray creek, elevation 5,000–7,000 feet., Aug. 10–18. Although *fulignosa* is the recognized breeding form for Vancouver island and inferentially the neighbouring coast, these birds from the higher elevations near the coast are typical *schistacea* and hence more nearly allied to the Rocky Mountain birds than coast birds. They were only seen in the one locality, and one juvenile bird suggests them to be breeders and not migrants.

65. Spotted Towhee, *Pipilo maculatus.*
♂ ♂ ♂ ♀, ♀ jv., Brackendale, June 8–18; ♂ ♂ ♀, ♀ jv., ♂ jv., ♂ jv. The Brackendale birds are clearly referable to *oregonus*, the Lillooet specimens to *montanus.*

66. Black-headed Grosbeak, *Zamelodia lelanocephala.*
♂ ♂ ♀ ♀, Brackendale, June 10–14.

67. Lazuli Bunting, *Passerina amoena.*
♂, Brackendale, ♂ ♂ ♀ ♀ ♀ ♀, Lillooet.

68. Western Tanager, *Piranga ludoviciana.*
♂ ♂ ♀ ♀ ♀, Brackendale, ♂ ♂ ♂ ♂ ♀ ♀ ♀ ♀, Lillooet.

69. Violet-green Swallow, *Tachycinata thalassina.*
♂ ♂ ♂ ♂, Brackendale, ♂ jv., ♂ ? jv., ♀ ♀, Lillooet.

70. Rough-winged Swallow, *Stelgidopteryx serripennis.*
♂ ♀, Brackendale, ♂ jv., ♂ jv., ♂ jv., ♀ ♀, Lillooet.

71. Bohemian Waxwing, *Bombycilla garrula.*
♂ ♀, ♀ jv., McGillivray creek, Aug. 16.
The juvenile is dark sooty greyish and quite striped below, indicating that it had probably been raised near by. The other two are apparently adult but with very light almost albinistic crest, due probably to the fading of unmoulted plumage.

72. Cedar Waxwing, *Bombycilla cedrorum.*
♂ ♀ ♀, Brackendale, ♂ ♂ ♀, ♂ ? jv.

73. Red-eyed Vireo, *Vireosylva olivacea.*
♂ ♂, Brackendale, ♀, Lillooet.

74. Warbling Vireo, *Vireosylva gilva.*
♂ ♂ ♂ ♀, Brackendale, ♂ ♀ ♀ ♀, Lillooet.
These all show the small size and the slightly dark colour of *swainsoni.*

75. Solitary Vireo, *Lanivereo solitarius.*
♂ ♂ ♂ ? ♀, Lillooet.
All evident *cassini.*

76. Nashville Warbler, *Vermivora rubricapilla.*
♂ ♂ ♀ ♀ ♂ jv., Lillooet.
All *gutteralis.*

77. Orange-crowned Warbler, *Vermivora celata.*
♀ jv., Lillooet.
In colour this specimen is intermediate between *celata* and *lutescens*, but larger than either. As this combination of intermediate colour and large size seems more or less common in a considerable series of birds from Edmonton, Alberta, to Vancouver island, B.C., the tenability of *orestera*, Oberholser, Auk, 1905, is partially confirmed. This may prove to be a recognizable form mingling during migrations with *celata* on the prairies and with *lutescens* west of the mountains. In this case the above specimen is *orestera*, otherwise it will have to be included in *lutescens.*

78. Yellow Warbler, *Dendroica aestiva.*
♂ ♂ ♂ ♂ ♀, Brackendale, ♂, Lillooet.
The distinctions between these and eastern birds are very slight indeed. They can be matched closely by Ontario specimens and without geography it would be difficult or impossible to identify them as *rubignosa.*

79. Audubon's Warbler, *Dendroica auduboni.*
♂ ♀, Brackendale; ♂, ♂ jv., ♂ jv., ♂ jv., ♂ jv., ♀ jv., Lillooet.

80. Black-throated Gray Warbler, *Dendroica nigrescens.*
♂ ♂ ♂ ♂ ♀, Brackendale; ♂ ♂ ♂ ♂ ♀ ♀, ♀ jv., Lillooet.

81. Townsend's Warbler, *Dendroica townsendi.*
♂ ♂ ♀ ♀ ♀, Brackendale, ♂ ♀ ? jv., Lillooet.

82. McGillivray's Warbler, *Oporornis tolmiei.*
♂ ♂ ♂ ♀, Brackendale; ♂ ♂ ♀, Lillooet.

83. Maryland Yellow-throat, *Geothlypis trichas.*
♂, ♂ jv., Brackendale.
Though these should according to the A. O. U. check-list be *arizela,* I can see no substantiation of that race in any Canadian specimen. All our specimens from the prairie and mountain provinces, including these, I refer to *occidentalis.*

84. Wilson's Warbler, *Wilsonia pusilla.*
♀, Brackendale.
Typical *pileolata.*

85. Redstart, *Setophaga ruticilla.*
♀, Brackendale, ♀, ♂ jv., Lillooet.

86. American Pipit, *Anthus rubescens.*
♂ jv., Brackendale, Sept. 5, ♀ ♀ ? Lillooet, altitude 7,000 feet, Aug 1. ♂ ♂ v., McGillivray creek, altitude 7,000 feet, Aug. 14-.17. Said to be breeding, which statement is substantiated by the soft condition of the Lillooet and McGillivray Creek juvenile plumage. The Brackendale bird is probably a migrant.

87. American Dipper, *Cinclus mexicanus.*
♂ ♀, Brackendale.

88. Catbird, *Dumatella carolinensis.*
♂, Brackendale, ♂ ♂ ♀, Lillooet.

89. Bewick's Wren, *Thryomanes bewicki.*
♂, Brackendale.
Being without eastern specimens I can only find subspecific determination by geography. It is doubtless *calophonus.*

90. House Wren, *Troglodytes aedon.*
♀, Brackendale.
Plainly *parkmani.*

91. Carolina Nuthatch, *Sitta carolinensis.*
♀, Lillooet.
Referred to *aculeata.*

92. Red-breasted Nuthatch, *Sitta canadensis.*
♀, Brackendale, ♂ ♂ ♂ jv., Lillooet.

93. Chickadee, *Penthestes atricapillus.*
♂ ♂ ♀ ♀ ♀, Lillooet, ♂, McGillivray creek.
In colour these birds exhibit slightly more white on wing coverts than eastern specimens show, and allowing for dirt and smoke stain on most eastern birds, are almost identical with them. However, the obviously longer tail designates these specimens to be *septentriona.*

94. Gambel's Chickadee, *Penthestes gambeli.*
♂ ♂ ♂ ♂ ♂ ♀ ♀ ♀, Lillooet.
Type form, *gambeli.*

95. Chestnut-backed Chickadee, *penthestes rufescens.*
♂ ♂ ♂, ♂ jv., ♀ ♀, Brackendale.

96. Townsend's solitaire, *Myadestes townsendi.*
♂ ♂, Brackendale, ♀ ♀, ♂ jv., Lillooet.

97. Wilson's Thrush, *Hylocichla fuscescens.*
Undoubtedly *salicicola.*

98. Alice's Thrush, *Hylocichla aliciae.*
♂ ♂ ♂ ♂ ♀ ♀, Lillooet, ♀ (?), Brackendale.

99. Hermit Thrush, *Hylocichla guttata.*
♀ Lillooet. This specimen is indistinguishable from worn birds from Trail, Rossland, and Skagit river, B.C. Allowing for the worn condition of its July plumage I cannot see that it differs from Victoria, Vancouver island, or Canmore, Alberta, birds, most of which are identified by Mr. Oberholser as *sequoyensis.* It is less brown and more greyish or olive than our only Queen Charlotte Island specimen that should be *nanus.* I, therefore, refer it to *sequoyensis.*

100. American Robin, *Planesticus migratorius.*
♂ ♀ ♂ jv., Brackendale, ♂ ♀ ♂ jv. ♀ jv., Lillooet.
All are without white tail spots, though one Lillooet male is comparable with many eastern birds. All are geographically *propinquus.* This race is a very fine differentiation.

101. Varied Thrush, *Ixoreus naevius.*
♂ ♀, Brackendale.

102. Western Bluebird, *Sialia mexicana.*
♀ jv., Brackendale.

103. Mountain Bluebird, *Sialia currucoides.*
♀ ♂ jv., ♀ jv., ♀ jv., Lillooet.

Preliminary List of Specimens Collected by C. H. Young and Wm. Spreadborough, in British Columbia, June to September, 1916.

(*R. M. Anderson.*)

1. Long-tailed Shrew. *Sorex longicauda longicauda* (Merriam).
♀, June 22, ♀, June 23, ♀ ♂, sex ?, June 24, Brackendale, Howe sound, B.C.

2. Navigator Shrew. *Neosorex navigator navigator* (Baird).
♂, July 22, Lillooet. Typical *navigator*.

3. Dark Yuma Bat. *Myotis yumanensis saturatus* Miller.
♂, June 15, Brackendale.

4. Silver-haired Bat. *Lasionycteris noctivagans* (Le Conte).
♂, Aug. 30, Brackendale.

5. Brown Bat. *Eptesicus fuscus* subsp.
♀, June 13, ♀ ♀, June 15, ♂, and 1 sex ?, June 23, Brackendale.

6. Pacific Coast Raccoon. *Procyon psora pacifica* Merriam.
♂, jv., Aug. 25, Brackendale.

7. Pacific Marten. *Martes caurina caurina* (Merriam).
♀ jv., July 18, ♀ jv., July 22, ♀ jv., July 28, Lillooet.
♂ ad., Aug. 12, McGillivray creek, Lillooet district, B.C., at 5,000 feet elevation.

8. Pacific Mink. *Mustela vison energumenos* (Bangs).
♀ ♀, August 29, Brackendale.

9. Common Weasel. *Mustela cicognanii cicognanii* Bonaparte.
♂, July 18, ♂, August 5, Lillooet.

10. Richly-coloured Weasel. *Mustela saturata* (Merriam).
♂, August 17, McGillivray creek, at 5,000 feet elevation.

11. White-footed Mice. *Peromyscus maniculatus* subsp.
♂ ♀, June 18, ♂, June 20, ♂ ♀, June 22, ♂, June 24, ♀, June 25, ♂, June 14, ♂ jv., June 23, Brackendale, Howe sound, at less than 100 feet elevation; referable to *Peromyscus maniculatus austerus* (Baird); dusky in colour, with broad dark wash along median line of back.

♂ ♂ ♂ jv., August 10, ♂, August 11, ♂, August 12, ♀, August 13, ♂ ♀, August 16, McGillivray creek, at 5,000 feet elevation ♀, July 4, ♂, July 31, Lillooet. Referable to *Peromyscus maniculatus oreas* (Bangs), averaging larger and more rufous-tinted than *austerus*. The last two specimens, from Lillooet, show a decided tendency to the greyer *artemisiae* type.

♂ ♂ ♀ ♂ jv., July 22, ♀, July 23, Lillooet; referable to *Peromyscus maniculatus artemisiae* (Rhoads); paler and greyer than any of the preceding specimens.

12. Bushy-tailed Wood Rat. *Neotoma cinerea drummondii* (Richardson).
♀, July 11, ♂, July 12, ♀, July 13, ♂, July 21, ♂, July 24, ♂, July 31, ♂, Aug. 1, ♀, Aug. 4, ♂, Aug. 5, Lillooet.
♂ ♂ ♀, Aug. 17, McGillivray creek, at 5,000 feet elevation.

13. Northwestern Red-backed Vole. *Evotomys caurinus* Bailey.
♀, June 25, Brackendale.

14. Olympic Meadow Vole. *Microtus macrurus* Merriam.
♀, June 26, Brackendale.

15. Meadow Vole. *Microtus mordax mordax* (Merriam).
♀, Aug. 14, ♂ jv. ♀ jv. ♂ ♀, Aug. 16, ♂ jv., Aug. 19, ♂, Aug. 20, ♀ ♀, Aug. 21, McGillivray creek, at 5,000 feet elevation.

16. Richardson's Meadow Vole. *Microtus richardsonii* subsp.
♂ ♀, August 12, ♀ ♂ jv., August 16, ♂ jv., August 19, at 5,000 feet elevation. Referable to the *richardsonii* group, although considerably larger and darker than specimen of *richardsonii* from Mica mountain (near Tête Jaune Cache, B.C.). Specimens are possibly *Microtus richardsonii arvicoloides* (Rhoads), to which they are doubtfully referred in the absence of specimens for comparison.

17. Rocky Mountain Muskrat. *Ondatra zibethica osoyoosensis* (Lord).
♂, June 24, Brackendale. Referable on geographical grounds to *O.z. osoyoosensis* (Lord); a very dark, richly-coloured specimen.

18. Northwest Jumping Mouse. *Zapus trinotatus trinotatus* Rhoads.
♀ ♀, August 29, Brackendale.
♂, August 12, McGillivray creek, at 5,000 feet elevation. All three specimens are very closely comparable to specimens in the Museum collection. The specimen from McGillivray creek has the dusky dorsal area better defined than the coast specimens.

19. Cascade Hoary Marmot. *Marmota caligata cascadensis* Howell.
♂ ad., August 10, at 6,000 feet elevation, ♀ jv., ♀ jv., August 12, at 5,500 feet elevation, McGillivray creek. The first (adult) specimen is very large and typical as to colour and skull proportions. The juvenal specimens, about one-third grown, show a uniformly brownish tint on posterior half of body, with a conspicuous whitish wash across the shoulders; crown and cheeks dark brown; nose and lips whitish; tail mixed with chestnut.

20. Streator's Chickaree. *Sciurus hudsonicus streatori* Allen.
♂, July 4, ♀, July 5, ♂ ♀, July 8, ♀ jv., July 20, ♂, August 1, Lillooet, at 700 to 1,500 feet elevation.
♂, August 21, McGillivray creek, at 5,000 feet elevation.

21. Cascade Mountains Chickaree. *Sciurus douglasii cascadensis* Allen.
♂ ♀, June 14, ♂, June 15, ♀, June 26, ♂, Sept. 6, Brackendale.

22. Chipmunks. *Eutamias quadrivittatus* subsp.
♀ ♂ jv., June 27, Brackendale, Howe sound. These are the dark reddish coast form, *E. q. felix* (Rhoads). No. 2714, ♂, August 14, at 7,000 feet elevation, and No. 2703, ♂ jv., August 11, at 6,500 feet elevation, McGillivray creek, on the east side of the Cascade Mountains divide, show much closer resemblance to coast specimens of ***felix*** than to other east Cascade specimens. The last two specimens have much rusty reddish in coat, and fur much longer, probably due to higher altitude and later date in the season.
♂ jv., July 4, ♂ ♀, jv., July 5, ♂, July 7, ♂ ♀, July 13, Lillooet, are probably referable to *E. q. affinis* (Allen), although showing more rufous in coat than other specimens from east of the Cascade range. The characters of the juvenal specimens are not distinct.

23. Dainty Pika. *Ochotona cuppes* Bangs.
♀, August 9, ♀, August 11, at 7,000 feet elevation, ♂, August 14, at 5,000 feet elevation, ♂ ♂ ♀, August 17, at 5,000 feet elevation, McGillivray creek. Specimens seem to be clearly referable to *O. cuppes* Bangs, averaging larger than *O. minima* (Lord), and more tawny than specimens of *O. princeps* (Richardson) from western Alberta.

24. Washington Hare. *Lepus washingtonii washingtonii* Baird.
♀ jv., June 17, ♂, June 18, ♀, June 19, ♀, June 27, Brackendale, Howe sound. The juvenal specimen of *L. w. washingtonii* is dull brown, with much blackish on top of head, and faint dusky median stripe.

25. Cascade Varying Hare. *Lepus bairdii cascadensis* Nelson.
♂ jv., July 15, ♀ jv., July 22, Lillooet. Juvenal specimens of *L. b. cascadensis* have much lighter colour than *L. w. washingtonii*, being uniformly tinged with yellowish brown; no black on head; face light yellowish brown; no dorsal median line.

Brackendale is on the Squamish river a few miles from Howe sound; the country to the west is mostly under cultivation; to the east very little has been cleared, but much of it has been burned over. Practically all collecting was done below 100 feet altitude.

Lillooet is on the east side of the Cascade mountains, at an altitude of 740 feet. The specimens were taken at altitudes between 700 and 1,500 feet above the sea. Lillooet is at the western edge of the "dry belt," sage-brush and cactus being found everywhere in the valley.

McGillivray creek, at the forks of the creek, at an altitude of 4,500 feet, about 40 miles west of Lillooet. Collecting was carried on up to 7,000 feet altitude; just on the east side of the Cascade Mountains divide. Information on the topography of the above localities was furnished by J. M. Macoun.

Preliminary List of Specimens taken by C. H. Young near Douglas, Manitoba, between May 22 and June 2, 1916.

(*P. A. Taverner.*)

Accession 16–29.

1. Black Tern, *Hydrocheledon nigra.*
♀.

2. Virginia Rail, *Rallus virginianus.*
♂.

3. Sora Rail, *Porzana carolina.*
♂.

4. Wilson's Phalarope, *Steganopus tricolor.*
♂ ♂ ♂ ♀ ♀ ♀ ♀ ♀ ♀, breeding.

5. Marbled Godwit, *Limosa fedoa.*
♂ ♂ ♂ ♂ ♂ ♀ (?).

6. Bartramian Sandpiper, *Bartramia longicauda.*
♂ ♀.

7. Prairie Chicken, *Tympanuchus americanus.*
♀, *americanus* by geography.

8. Mourning Dove, *Zenaidura macroura.*
♂ ♀ ?

9. Nighthawk, *Chordeiles virginianus.*
♂ ♀. These birds average rather dark on the upper parts though the spotting of the wing coverts is sharply contrasted. I refer them to the typical form *virginianus.*

10. Kingbird, *Tyrannus tyrannus.*
♂.

11. Least Flycatcher, *Empidonax minimus.*
♂ ♀.

12. Horned Lark, *Otocoris alpestris.*
♂ ♂ ♂ ♂ ♀, fledgling. These birds are all similar in coloration. The fledgling intimates that they are the breeding birds of the locality. I refer them to *praticola.*

13. Bobolink, *Dolichonyx oryzivorus.*
♂ ♂ ♀ ♀.

14. Cowbird, *Molothrus ater.*
♂.

15. Red-winged Blackbird, *Agelaius phœniceus.*
♂ ♂ ♀ ♀ according to the A. O. U. distributions the birds from the prairies should be *fortis.* The birds from this section, however, do not fulfil the original description of this form and do agree with the characters of *arctolegus* proposed by H. C. Oberholser. I, therefore, refer them to that race. The subspecific distinctions between these races, however, seem to be very slight.

16. Brewer's Blackbird, *Euphagus cyanocephalus.*
♂ ♀.

17. Chestnut-collared Longspur, *Calcarius ornatus*.
♂ ♂ ♀ ♀.

18. Vesper Sparrow, *Poœcetes gramineus*.
♂, nearly typical *confinis*.

19. Savannah Sparrow, *Passerculus sandwichensis*.
♂ ♀, The subspecific status of the Canadian Great Plains birds of this species cannot be unrestrictedly referred to. They differ essentially from *alaudinus* as indicated by Bonaparte's original description or by that of Ridgway, especially in the brilliancy of the yellow superciliary line. They are practically intermediate in colour between eastern *savanna* and the British Columbia birds spoken of elsewhere in this report, but have the small bill of the latter. Of these Douglas specimens, the male is typical *savanna* except for a small bill while the female is of the usual prairie form—characteristic *alaudinus* except for a darker back more closely approaching *savanna*.

20. Leconte's Sparrow, *passerherbulus lecontei*.
♂ ♂.

21. Nelson's Sparrow, *Passerherbulus nelsoni*.
♂ ♂ ♂, typical *nelsoni*.

22. Chipping Sparrow, *Spizella passerina*.
♂ ♀. The difference between these and eastern birds is very slight indeed and they are referred to *arizonæ* for geographical reasons rather than determinative characters.

23. Clay-coloured Sparrow, *Spizella pallida*.
♂ ♂ ♂ ♀.

24. Swamp Sparrow, *Melospiza georgiana*.
♀ ♀.

25. Rose-breasted Grosbeak, *Zamelodia ludoviciana*.
♂.

26. Barn Swallow, *Hirundo erythrogastra*.

27. Loggerhead Shrike, *Lanius ludovicianus*.
♂. The various races of the Loggerhead Shrike are poorly defined and their subspecific characters do not seem to be firmly fixed. Individual variation is so great that it often equals or even exceeds subspecific limits and very few specimens are typical. Each feature of this specimen can be Matched in specimens that should geographically be typical *migrans*. The closest identification to be arrived at is to call it intermediate between *migrans* and *exubitorides*.

28. Orange-crowned Warbler, *Vermivora celata*.
♂, typical *celata*.

29. Yellow Warbler, *Dendroica æstiva.*
♂, typical *æstiva.*

30. Maryland Yellow-throat, *Ceothlypis trichas.*
♀, not subspecifically identified.

31. Short-billed Marsh Wren, *Cistothorus stellaris.*
♂ ♀.

32. Alice's Thrush, *Hylocichla aliciæ.*
♀, typical *aliciæ.*

33. Bluebird, *Sialis sialis.*
♂ ♀.

CANADIAN ARCTIC EXPEDITION, 1916.—ZOOLOGY.

(*R. M. Anderson.*)

Since my last published report to the department, dated July 29, 1915, the zoological work of the expedition has proceeded as follows:

I spent the remainder of the summer and autumn of 1915 in field work with the eastern topographical and geological survey party, traversing with motor boats the region eastward from cape Barrow—around Moore bay and Arctic sound, up Hood river to the first cascade, and well down into Bathurst inlet (below the Barry islands), taking representative collections of birds and mammals, some specimens of plants, a few fishes, etc. During the summer J. J. O'Neill and J. R. Cox collected a good series of the plants in the region about Port Epworth and up Tree river, as well as a few interesting bird and mammal specimens.

Our boat survey returned as far as Tree river, and sledged home from there to Bernard harbour, following the south coast of Coronation gulf, and reaching the winter quarters on November 9. Our summer's collections were hauled from Port Epworth to Bernard harbour by sledge later in the winter. While spending the summer with the Eskimos in the interior of Victoria island, Mr. Jenness collected a few birds, but as he was packing from place to place most of the time, necessarily he could not preserve many specimens. Mr. Johansen devoted his time to entomology, botany, and marine and freshwater biology in the vicinity of Bernard harbour. During the months of January and February, 1916, I went inland a little distance above the most northern trees on Coppermine river, and although caribou were fairly numerous, the season was unfavourable for collecting many other specimens. Mr. Johansen collected a few zoological specimens along the south coast of Victoria island in March and April, 1916.

The greater part of the month of March, 1916, the writer spent with Mr. K. G. Chipman making a reconnaissance up Croker river into the middle of a hitherto unexplored region lying between Darnley bay and Dolphin and Union strait. The region was interesting, although the zoological results were mainly negative. Starting out again in April, 1916, I made another sledge trip eastward visiting Coronation gulf and Bathurst inlet, returning to Bernard harbour June 6. A number of valuable specimens and many photographs were obtained on this trip. Collections of various kinds were made around the station until the *Alaska* sailed on July 13, 1916. We followed the coast pretty closely on the way out, teaching Young point on July 17, Pierce Point harbour July 23, cape Bathurst

(or Baillie islands) July 24, Herschell island, Y.T., July 28, International Boundary August 4, cape Barrow, Alaska, August 8, point Hope, Alaska, August 10, passing through Bering strait August 11, and reaching Nome, Alaska, August 15, 1916. Small miscellaneous collections were made at most of the places where we stopped on the way out.

Of the larger mammals, our collections include good series of Polar Bear, Barren Ground Bear, Barren Ground Caribou, Barren Ground Wolf, Arctic Fox, Red Fox, Wolverine, Arctic Hare, and seals, besides many smaller species. Large series of Barren Ground Caribou were collected during the autumn migration south from Victoria island in November, some specimens during the spring migration, some young fawns in June, and a few summer specimens from the eastern region.

The collection of Arctic Foxes, the principal economic fur-bearing animal of the regions visited, is noteworthy in representing practically every condition of age, sex, and change of pelage, including specimens taken during ten different months of the year.

The Wolverine is surprisingly numerous on the coast and islands of Coronation gulf and Bathurst inlet, in some cases more than 100 miles from any timber, and is of especial note and importance because nothing edible can be left long without being molested or disturbed by it. Twelve good specimens were taken and preserved.

It has been practically demonstrated by the travels of our numerous field parties and from credible information derived from the natives of the country, that the Musk-ox does not exist at the present time anywhere near the coast at any point west of Annielik river, which flows into Gray bay, some 75 miles east of the mouth of Coppermine river. The Musk-ox has become extinct along the lower part of Coppermine river and practically extinct around Great Bear lake, although there is evidence to show that there are still a few left on the north side of the lake. Mr. Wilkins informs me that extensive travels on Banks island in 1914-1916 have shown no trace of the Musk-ox existing at present on that large island, although skeletal remains are numerous.

The bird collections contain representatives of most of the species found in the regions traversed, and fairly large series of some species. The difficulty of transportation and preservation of specimens while on extended trips, and the pressure of executive duties at other times, often prevented the obtaining of as large series as desirable. The collection of birds numbers six hundred and nineteen (619) specimens, including seventy-three (73) species. The collection of mammals numbers four hundred and thirty-one (431) specimens, including twenty-two (22) species and probably several subspecies. All of the collections were shipped from Nome, Alaska, and reached Ottawa early in October, 1916. It is not possible to tell without more detailed examination whether any new forms are represented, but many specimens represent seasonal plumages and pelages, juvenal specimens and moults, which are rare in collections; and the specimens which were taken will widely extend the known geographical range of a number of species. The notes on the life histories and ecology are also extensive and important. The work in mammalogy and ornithology, while in the particular field of the writer, was materially aided by all members of the expedition, who by their cheerful and continued co-operation brought in many valuable specimens and notes which would otherwise not have been obtained. Mr. George H. Wilkins in particular, who was with the northern party of the expedition for some time, made quite a collection of both mammals and birds from the vicinity of cape Kellett, Banks island.

Preliminary List of Specimens Collected by the Canadian Arctic Expedition, 1914 to 1916. Identified by Rudolph Martin Anderson.

Accessions 15–100 and 16–56.

1. Horned Grebe. *Colymbus auritus* Linnaeus.
   ♂ ad. Summer. Firth river, Y.T., near Herschell island.

2. Yellow-billed Loon. *Gavia adamsi* (Gray).
   ad. ♂♂♂♂♂♂♂♂♀♀♀♀, 2 sex unknown. July 13, mouth of Hula-hula river, Alaska. June 28 to July 20, Franklin bay. June 25 to July 24, Bernard harbour, Dolphin and Union strait, N.W.T. July 16, Port Epworth, Coronation Gulf. Aug. 2, Gray bay, Coronation gulf. June 30, Salmon river, Alaska, with one egg.

3. Pacific Loon. *Gavia pacifica* (Lawrence).
   ad. ♂♂♂♂♂♀♀, 2 sex unknown. June 18, July 2–5, Barter island, Alaska. June 28, July 5, Aug. 5–7, Bernard harbour; October, mouth of the Coppermine river.

4. Red-throated Loon. *Gavia stellata* (Pontoppidan).
   ad. ♂♀♀♀♀, 1 sex unknown. Spring, Baillie island. July 5, 6, 11, Bernard harbour.
   juv. ♀, changing from downy plumage, Aug. 27, Bernard harbour.

5. Mandt's Guillemot. *Cepphus mandti* (Mandt).
   ad. ♀, Feb. 17, point Barrow, Alaska. Winter plumage.

6. Pomarine Jaeger. *Stercorarius pomarinus* (Temminck).
   ad. ♀ dark phase, June 15, Franklin bay.
   ad. ♀♀♀♀♀♀♀♀♀, light phase, June 10, 12, 15, 16, 18, 30, Bernard harbour.
   ad. 3 sex unknown, Sept. 3–4, cape Kellett, Banks island.
   juv. 2 sex unknown, Sept. 3, cape Kellett, in dark barred plumage.

7. Parasitic Jaeger. *Stercorarius parasiticus* (Linnaeus).
   ad. ♀, light phase, July 5, Barter island, Alaska.
   ad. ♀♀, 1 sex unknown, June 28, July 15, Bernard harbour.
   ad. ♀, July 6, cape Kellett, Banks island.
   juv. ♀, Sept. 23, cape Bathurst. Dark barred plumage.

8. Long-tailed Jaeger. *Stercorarius longicaudus* Vieillot.
   ad. ♀, June 28, Bernard harbour.
   ad. ♂, July 12, Franklin bay.
   ad. ♂, and 1 sex unknown, June 18, 30, cape Kellett, Banks island.

9. Glaucous Gull. *Larus hyperboreus* Gunnerus.
   ad. ♂♂♂♂♀♀♀♀♀, Sept. 25, Sept. 19, 30, May 31, June 9, Bernard harbour, Cockburn point, Chantry island.

10. Thayer's Gull. *Larus thayeri* Brooks.
    ad. ♂ ♀, June 19, Bernard harbour.
    ad. ♂, Aug. 20, Kater point, Arctic sound (breeding).
    ad. ♀ ♀, 2 sex unknown, June 7–16, Sept. 6–17, **jv.**, cape Kellett, Banks island.
    All the adult specimens of black-winged gulls have been examined by Dr. Jonathan Dwight and by him referred to the new species *thayeri.* The juvenal specimens are probably the same species.

11. Sabines' Gull. *Xema sabini* (J. Sabine).
    ad. ♂ ♀, 1 sex unknown, June 26–30, Barter island, Alaska.
    ad. ♂ ♂ ♂ ♀ ♀ ♀ ♀ ♀ ♀, June 14, 15, 17, 19, Bernard harbour, N.W.T.
    ad. sex unknown, near albino, September, Baillie island, N.W.T.

12. Arctic Tern. *Sterna paradisæa* Brünnich.
    ad. ♀, June 20, Barter island, Alaska.
    ad. ♀, July 26, cape Bathurst.
    ad. ♀, July 15, Cockburn point, N.W.T. (breeding).

13. Leach's Petrel. *Oceanodroma leucorhoa* (Vieillot).
    ad. ♀, Aug. 31, gulf of Alaska, south of Unimak pass, between Unimak island and Akutan island, Aleutian islands, Alaska.

14. Pintail. *Dafila acuta* (Linnaeus).
    ad. ♀, June 24, Barter island, Alaska.

15. Old-squaw. Long-tailed Duck. *Harelda hyemalis* (Linnaeus).
    ad. ♂ ♂, June 8, July 5, Franklin bay.
    ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♀, June 12, 13, 14, 23, July 9, 11, Bernard harbour.
    ad. ♂, moulting, Bernard harbour.
    ad. ♂, moulting, Detention harbour, Coronation gulf.
    ad. ♂ ♂ ♂ ♂, June 22, July 12, cape Kellett, Banks island.

16. Harlequin Duck. *Histrionicus histrionicus* (Linnaeus).
    ad. ♂ ♂, June 26, Barter island, Arctic coast of Alaska.
    ad. ♂, June 10, Escape reef, Mackenzie bay, Y.T.
    ad. ♂, summer, Firth river, Y.T., near Herschell island.

17. Steller's Eider. *Polysticta stelleri* (Pallas).
    ad. ♂ ♂ ♀, June, Barter island, Arctic coast of Alaska.

18. Spectacled Eider. *Arctonetta fischeri* (Brandt).
    ad. ♂ ♀, June 29, Barter island, Arctic coast of Alaska.

19. Pacific Eider. *Somateria v-nigra* Gray.
    ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀, mostly in breeding plumage, but some moulting ("eclipse") plumage, May 30–31, June 9, 12, 14, 25, 29, 30, July 2, 21, 29, Aug. 8, Sept. 24, 28, Barter island, Alaska; Franklin bay, N.W.T., Cockburn point, Bernard harbour, Inman harbour, Coronation gulf.
    ad. moulting, Franklin bay, July 2–21; Bernard harbour, Aug. 8.
    juv. downy specimens, alcoholic specimens.

20. King Eider. *Somateria spectabilis* (Linnaeus).
ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀, mostly in full breeding plumage, but some moulting and autumn plumages. June 22, 23, 24, 25, 28, 30, July 4, 5, 6, 7, 14, Aug. 27, 30, Sept. 25, May 31. Franklin bay, Liverpool bay, Bernard harbour, N.W.T.
juv. ♂, downy plumage, Aug. 27, Bernard harbour.

21. White-winged Scoter. *Oidemia deglandi* Bonaparte.
ad. ♂, May, 1915, cape Bathurst, N.W.T.

22. Snow Goose. *Chen hyperboreus hyperboreus* (Pallas).
ad. ♂ ♀, June 18, 19, full plumage, cape Kellett, Banks island.
ad. ♂ ♂, July 19, 20, moulting quills, cape Kellett, Banks island.

23. Hutchins's Goose. *Branta canadensis hutchinsi* (Richardson).
ad. ♂, June 17, Bernard harbour, N.W.T.

24. Black Brant. *Branta nigricans* (Lawrence).
ad. ♀, July 11, Franklin bay.
ad. ♂ ♂ ♀ ♀, June 9, Aug. 31, cape Kellett, Banks island.

25. Little Brown Crane. *Grus canadensis* (Linnaeus).
ad. sex unknown, Escape reef, Mackenzie bay, Y.T.
ad. ♂, June 17, Cape Kellett, Banks island.

26 Red Phalarope. *Phalaropus, fulicarius* (Linnaeus).
♀, Sept. 30, cape Bathurst, N.W.T.

27. Stilt Sandpiper. *Micropalama himantopus* (Bonaparte).
ad. ♀, June 22, Bernard harbour, N.W.T.

28. Pectoral Sandpiper. *Pisobia maculata* (Vieillot).
ad. sex unknown, June 5, Barter island, Alaska. Breeding.
ad. ♀, ad. sex unknown, Aug. 4, Bernard harbour, N.W.T.
ad. ♀, June 16, Barter island, Alaska, with eggs and nest.

29. White-rumped Sandpiper. *Pisobia fuscicollis* (Vieillot).
ad. ♀, June 20, cape Kellett, Banks island.

30. Baird's Sandpiper. *Pisobia bairdi* (Coues).
ad. ♂, June 19, Bernard harbour, N.W.T. ad. ♂ ♂ ♂, June 19, Aug. 4.
ad. sex unknown, June 12, Barter island, Alaska, with eggs.
2 downy young, June 30. 4 downy young, July 3. 4 downy young, July 14. 3 downy young, July 19. 2 juv. July 21. 1 juv. July 26. Bernard harbour, N.W.T.

31. Semipalmated Sandpiper. *Ereunetes pusillus* (Linnaeus).
ad. sex unknown, June 17, Barter island, Alaska, with eggs.

32. Sanderling. *Calidris leucophaea* (Pallas).
ad. sex unknown, June 16, Barter island, Alaska.
ad. ♂, June 22, Bernard harbour, N.W.T.
ad. ♂ ♀ ♀, July 26, cape Bathurst, N.W.T.
ad. sex unknown, 2 specimens, Aug. 24, cape Lambton, Banks island.

33. Buff-breasted Sandpiper. *Tryngites subruficollis* (Vieillot).
    ad. ♂ ♀, June 6, Bernard harbour, N.W.T. Breeding.

34. Black-bellied Plover. *Squatarola squatarola* (Linnaeus).
    ad. ♀ Barter island, Arctic coast of Alaska, June 22.
    ad. ♂ ♂ ♀ ♀, June 10, 16, 22, 26, Bernard harbour.
    ad. ♂, Colville hills, interior Victoria island, June 16.
    ad. ♂ ♂ ♂, June 18, 19, July 4, cape Kellett, Banks island.
    juv. 3 sex unknown, Sept. 4, 6, cape Kellett, Banks island.

35. Golden Plover. *Charadrius dominicus dominicus* (Müller).
    ad. ♀, ad. sex unknown, July 14, Camden bay, Alaska.
    ad. ♂ ♂ ♂ ♂ ♀ ♀ ♀, June 17, 19, 28, 25, May 28, Bernard harbour.

36. Semipalmated Plover. *Ægialitis semipalmata* (Bonaparte).
    ad. ♂ ♂, June 6, 19, 20, Bernard harbour, N.W.T.
    2 juv. downy, July 21; Bernard harbour.
    ad. sex unknown, with eggs, June 30, Port Epworth, Coronation gulf.
    juv. ♀ ♀ ♀, Aug. 16, 17, Detention harbour, Galena point, Coronation gulf.
    ad. ♀, Young point, Amundsen gulf, July 18.

37. Ruddy Turnstone. *Arenaria interpres morinella* (Linnaeus).
    ad. ♀, June 22, Bernard harbour, N.W.T.
    ad. ♂, June 5, Colville hills, Victoria island.
    ad. ♂, June 19, Port Epworth, Coronation gulf.

38. Willow Ptarmigan. *Lagopus lagopus lagopus* (Linnaeus).
    ad. ♂ ♂, Feb. 7, ad. ♀, March 25, Bernard harbour.
    ad. ♂ ♂ ♂ ♀, 1 sex unknown, June 23, Sept. 12, 25, Oct. 7, 9, cape Kellett, Banks island.
    ad. ♀, April 5, Cache point, Victoria island.

39. Rock Ptarmigan. *Lagopus rupestris rupestris* (Gmelin).
    ad. ♂ ♂ ♀, Kay point, Arctic coast of Y. T., Aug. 17-18.
    ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂, ♀ ♀ ♀, March 30, May 31, April 30, June 16, Sept. 23, Oct. 1, Sept. 30, Bernard harbour, N.W.T.
    ad. ♂ ♂, Aug. 19, Moore bay, Coronation gulf.
    ad. ♂ ♀, Sept. 3, Bathurst inlet.
    ad. ♂ ♂ ♂ ♀, Sept. 5, 12, 25, cape Kellett, Banks island.

40. Rough-legged Hawk. *Archibuteo lagopus sancti-johannis* (Gmelin).
    ad. ♂ ♂, Sept. 12, Franklin bay.
    ad. ♂, May 30, mouth of Kogaryuak river, Coronation gulf, nesting.
    ad. sex unknown, June 17, Port Epworth, Coronation gulf, nesting.

41. White Gyrfalcon. *Falco islandus* Brünnich.
    ad. ♀, Sept. 9, Bernard harbour, N.W.T.

42. Gray Gyrfalcon. *Falco rusticolus rusticolus* Linnaeus.
    ad. ♂, Sept. 29, Franklin bay.

43. Gyrfalcon. *Falco rusticolus gyrfalco* Linnaeus.
ad. ♂ ♀, Sept. 9, Sept. 10, cape Bathurst, N.W.T.
These specimens of Gyrfalcons show a tendency to intermediate characters, but under the accepted classification may be separated as above.

44. Duck Hawk. *Falco peregrinus anatum* Tunstall.
ad. ♂, June 16, Barter island, Alaska.
ad. ♀, Sept. 9, Bernard harbour, N.W.T.

45. Short-eared Owl. *Asio flammeus* (Pontoppidan).
ad. ♀, May 26, Franklin bay, N.W.T.
ad. ♂, June 18, Bernard harbour, N.W.T.

46. Snowy Owl. *Nyctea nyctea* (Linnaeus).
ad. sex unknown, June, Nunaluk, coast of Yukon Territory.
ad. ♀, Oct. 1, cape Bathurst, N.W.T.
ad. ♂, Oct. 8, Cockburn point, N.W.T.
ad. ♂ ♂ ♀ ♀, 1 sex unknown, Sept. 26, Oct. 5, 13, Nov. 20, Dec. 8, cape Kellett, Banks island.
juvenal, ♂ ♀ ♀, 2 sex unknown, Sept. 5, 8, cape Kellett, Banks island.

47. Hawk Owl. *Surnia ulula caparoch* (Müller).
2 specimens, sex unknown, Dec. 21, 1915, on divide of Endicott mountains, Alaska, near International Boundary.

48. Hoyt's Horned Lark. *Otocoris alpestris hoyti* Bishop.
ad. ♂ ♂, May 21, Wise point, Amundsen gulf.
ad. ♂ ♂ ♀, May 30, July 31, Aug. 6, Bernard harbour, N.W.T.
ad. ♂ ♂, June 10, Colville hills, Victoria island.
ad. ♂, May 26, Port Epworth, Coronation gulf.
juv. ♂ ♂ ♂, July 20, 26; ♂ ♂ ♀ ♀, Aug. 2; ♀ ♀, Aug. 6, Bernard harbour, N.W.T.

49. Alaska Jay. *Perisoreus canadensis fumifrons* Ridgway.
ad. ♂, 3 sex unknown, Aug. 23, 27, Sept. 12, 13, Endicott mountains, on tributary of Salmon river, Alaska.

50. Northern Raven. *Corvus corax principalis* Ridgway.
ad. ♂ ♂, June 20, Nov. 7, Bernard harbour, N.W.T.
ad. ♀, Aug. 7, moulting, Bernard harbour, N.W.T.
ad. ♂ ?, Sept. 17, Banks island.

51. Redpoll. *Acanthis* sp.
ad. ♂, March 1, cape Lambert, Dolphin and Union strait.
♀, August 27, Hood river, Arctic sound, N.W.T.

52. Snow Bunting. *Plectrophenax nivalis nivalis* (Linnaeus).
ad. ♂ ♂ ♂ ♂ ♂ ♀ ♀ ♀, June 22, 19, July 4, 8, Aug. 2, Bernard harbour.
juv. ♂ ♂, July 28, Bernard harbour; Aug. 14, cape Barrow, Coronation gulf.

53. Lapland Longspur. *Calcarius lapponicus lapponicus* (Linnaeus).
ad. ♂ ♂ ♀ ♀ ♀ ♀ ♀, May 30, June 11, 19, July 1, Aug. 4,5, Bernard harbour.
ad. ♂ ♀, Aug. 14, cape Barrow, Coronation gulf; juv. Aug. 14.
juv. ♂ ♂ ♀ July 3; juv. July 21, 22, 24, 26; Bernard harbour.
juv. 4, alcoholic specimens, July 8, Bernard harbour.

54. Western Savannah Sparrow. *Passerculus sandwichensis alaudinus* Bonaparte.
ad. ♂, Oct. 11, mouth of Tree river, Kogluktualuk, Port Epworth, Coronation gulf,

55. Tree Sparrow. *Spizella monticola monticola* (Gmelin).
ad. ♀, Aug. 27, mouth of Hood river, Arctic sound, N.W.T.

56. Slate-coloured Junco. *Junco hyemalis hyemalis* (Linnaeus).
ad. ♂, Oct. 11, 1915, mouth of Tree river, Coronation gulf.
ad. ♀, Bernard harbour, Dolphin and Union strait, N.W.T.

57. Northern Shrike. *Lanius borealis* Vieillot.
ad. ♀, June 29, Salmon river, north of Fort Yukon, Alaska, breeding.

58. Orange-crowned Warbler. *Vermivora celata celata* (Say).
ad. ♂, Wise point, Amundsen gulf, N.W.T.
juv. sex unknown, Sept. 28, Bernard harbour, N.W.T.

59. Grinnell's Water-Thrush. *Seiurus noveboracensis notabilis* Ridgway.
ad. sex unknown, Sept. 11, cape Kellett, Banks island.

60. Pipit. *Anthus rubescens* (Tunstall).
ad. ♂, Aug. 13, cape Barrow, Coronation gulf.
ad. ♀, Aug. 19, Moore bay, Coronation gulf.

61. Robin. *Planesticus migratorius migratorius* (Linnaeus).
ad. ♂ ♀, June 1. Turner river, Arctic Alaska, near International Boundary. Breeding.

61 species, 411 specimens, in 1916 accessions from C. A. E.
52 " 208 " " 1914 " " "

There were twelve species in 1914 accession not represented in 1916 accession, including Pallas's Murre, Pacific Kittiwake, Short-billed Gull, Red-breasted Merganser, Surf Scoter, White-fronted Goose, Northern Phalarope, Red-backed Sandpiper, Western Sandpiper, Hudsonian Curlew, Fox Sparrow, Alaska Yellow Wagtail.

Total, 1913-1916, 73 species, 619 specimens.

Preliminary List of Specimens of Mammals Collected by the Canadian Arctic Expedition, 1914 to 1916. Identified by Rudolph Martin Anderson.

1. Barren Ground Caribou. *Rangifer arcticus* (Richardson).
ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂, Nov. 16, Feb. 26, Bernard harbour, Dolphin and Union strait, N. W. T.
ad. ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀, April 3, 7, 18, Nov. 16, 20, Feb. 26, Bernard harbour.

juv. ♀ ♀ ♀ ♀, fawns, June 5, 12, 23, Sept. 23, Bernard harbour.
ad. ♂ ♂ ♂, Aug. 24, 27, Sept. 3, Kater point, Hood river, Kannoyuk island (Bathurst inlet).
ad. ♀ juv. ♀, Oct. 5, Tree river, Coronation gulf.
ad. ♂ ♀, March 19, 21, southern Victoria island.
juv. ♀, April 15, Liston island, Dolphin and Union strait.
ad. ♂ ♂ ♂ ♀ ♀ ♀ ♀, Oct. 9, 11, 14, Nov. 1, cape Kellett, Banks island.

2. Musk-ox. *Ovibos moschatus* subsp. ?
ad. ♂ ♂, imperfect skins; summer skin of calf, sex unknown; skin of unborn calf; taken by Eskimos south of Arctic sound, N.W.T., in spring and summer of 1915.

3. Parry's Spermophile. *Citellus parryi* subsp. ?
Specimens are probably referable both to Hudson Bay Spermophile (*Citellus parryi*) and Mackenzie Spermophile (*Citellus parryi kennicotti*).
ad. ♀, Aug. 18, Kay point, Y. T.
ad. ♀, May 11, Deas Thompson point, Amundsen gulf, N. W. T.
ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂, ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀, May 16, 20, 29, 30, June 2, 6, 7, July 22, Sept. 2, 27, Bernard harbour, N. W. T.
ad. ♂, Aug. 4, cape Barrow, Coronation gulf. Also a number of spring (May) skins from cape Barrow, without skulls.
ad. ♂, albino, summer, cape Barrow, Coronation gulf.
Also a number of summer skins, without skulls, from mouth of Coppermine river, N. W. T.

4. Hudson Bay Red Squirrel. *Sciurus husdonicus hudsonicus* (Erxleben).
Skin, purchased from Coppermine River Eskimo; probably from Dease river, northeast end of Great Bear lake, N. W. T.

5. Arctic White-footed Mouse. *Peromyscus maniculatus borealis* Mearns.
ad. ♂, Aug. 6, Herschell island, Y. T. Caught in Hudson's Bay Company's scow from Peel river and Mackenzie River delta.

6. Red-backed Mouse. *Evotomys* sp.
ad. ♂ ♂ ♀, May 25, 26, 1916. Three specimens taken in rock food cache on island in Port Epworth harbour, at mouth of Tree river (Kogluktualuk), Coronation gulf, were the only specimens of this genus I have seen on or near the Arctic coast.

7. Brown Lemmings. *Lemmus* sp.
ad. ♀, June 3, Bernard harbour, N. W. T.
ad. ♂, July 6, cape Kellett, Banks island.
ad. sex unknown, June 21, Port Epworth, Coronation gulf.

8. Fork-clawed Lemmings. *Dicrostonyx* sp.
ad. ♂ ♂ ♂ ♂ (changing pelage), Oct. 12, 13, 15, Nov. 5, cape Bathurst.
ad. ♂ (summer), Aug. 30, Bernard harbour; ad. ♀ (summer), May 30, Coronation gulf.
ad. ♂, (changing), May 17, Bathurst inlet.
ad. ♀ ♀, juv. ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♀, July 4, 7, Bernard harbour.
ad. ♂ ♂ ♂, Oct. 3, November, Bernard harbour.
ad. ♂ ♂, 2 sex unknown, July 6, Sept. 5, 8, cape Kellett, Banks island.

9. Lemming Vole. *Synaptomys* sp?
   ad. ♀, May 25, on island in Port Epworth harbour, mouth of Tree river, Coronation gulf, N. W. T.

10. Vole. *Microtus* sp?
    ad. ♂ ♂, October 3, 4, Collinson point, Arctic coast of Alaska.

11. Northwest Muskrat. *Ondatra zibethica spatulata* (Osgood).
    adult albino, spring, 1916, west branch of Mackenzie River delta.

12. Arctic Hare. *Lepus arcticus* subsp?
    ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ (12), ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ (10), 1 sex unknown, March 19, 24, 25, February 15, April 25, May 17, June 2, July 3, Aug. 11, 14, Sept. 1, 26, 28, 30, Oct. 7, Nov. 1, Bernard harbour, Cockburn point, cape Krusenstern (Dolphin and Union strait), cape Kendall, Port Epworth, Gray bay, cape Barrow, (Coronation gulf), Bathurst inlet, Victoria island.
    ad., 1, sex unknown, Dec. 4, cape Kellett, Banks island.

13. Barren Ground Wolf. *Canis* sp?
    ad. ♀, February 10, Bloody fall, Coppermine river, N. W. T.
    ad. ♂, October, Rae river, west side of Coronation gulf.
    ad. ♂ ♀, June 19, July 20, falls of Tree river (Kogluktualuk), Port Epworth, Coronation gulf.
    ad. ♂, Kater point, Arctic sound, N. W. T.
    ad. ♂ ♂ ♂, ♀, Sept. 9, Dec. 14, 15, Feb. 27, cape Kellett, Banks island.

14. Red Fox. *Vulpes alascensis*?
    ad. ♂, Oct. 19, Bernard harbour, Dolphin and Union strait.
    ad. ♂, ♀ ♀, November, Port Epworth, Coronation gulf.
    ad. sex unknown, cross phase, south side of Arctic sound.

15. Arctic Fox. *Alopex lagopus innuitus* (Merriam).
    ad. ♂, blue phase, Oct.-Nov., Simpson bay, Victoria island.
    ad. ♂ ♀, blue phase, December, cape Bathurst, N. W. T.
    ad. ♂ ♂, juv. ♀ ♀ ♀, Sept. 22, 25, Oct. 4, cape Bathurst, N. W. T.
    ad. ♂, changing, May 17, Bathurst inlet, N. W. T.
    ad. ♂ ♂, ♀ ♀, November, Port Epworth, Coronation gulf.
    ad. ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ ♂ (13), ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ ♀ (18), Sept. 23, November 4, 7, 10, 13, 25, 26, 28, 30, December 1, 2, 5, 6, 10, 11, 12, 13, Bernard harbour, N. W. T.
    4 specimens, sex unknown, summer and autumn, Bernard harbour.
    71 specimens, adults and young, many phases of transition from young summer specimens to white winter adults, 2 specimens January, 1 February, 2 March, 1 April, 3 August, 1 September, 42 October, 12 November, 4 December; 3 winter, no data—cape Kellett, Banks island.

16. Barren Ground Bear. *Ursus richardsoni* Swainson
    ad. ♂ ♂ ♂ ♂ ♂, skins with skulls, Aug. 28, September, and mid-summer—Arctic sound, Stapylton bay, Bernard harbour, Rae river, and mouth of Coppermine river.
    4 skins, sex unknown, summer, 1915, from Barren Grounds south of Arctic sound, N. W. T.

17. Polar Bear. *Thalarctos maritimus* (Phipps).
    juv. ♀, May 17, DeWitt Clinton point, Amundsen gulf, N. W. T.
    ad. ♀, juv. ♀, Sept. 28, cape Bathurst, N. W. T.
    ad. ♀, juv. ♀, Oct. 2, cape Bathurst.
    ad. ♀, juv. ♂ ♀, Oct. 12, cape Bathurst.
    ad. ♀, Oct. 26, cape Bathurst.
    ad. ♂ ♀, juv. ♂ ♀, Nov. 12, cape Bathurst.
    2 skins, sex unknown, cape Kellett, Banks island.

18. Alaska Mink. *Mustela vison ingens* (Osgood).
    ad. ♂, winter, Mackenzie River delta.

19. Tundra Weasel. *Mustela arctica* subsp.
    ad. ♂ ♀, July 8, 9, Barter island, Alaska.
    ad. ♂, Sept. 8, east Barry island, Bathurst inlet, N. W. T.
    9 specimens, sex unknown, autumn, Dolphin and Union strait.

20. Hudson Bay Wolverine. *Gulo luscus* (Linnaeus).
    ad. ♂ ♂ ♂ ♂ ♂ (5), ♀ ♀ ♀ ♀ ♀ ♀ ♀ (7), Feb. 22, 27, March, Aug. 19, September 9, November.
    Chantry island (Dolphin and Union strait), mouth of Coppermine river, Duke of York archipelago, Tree river, (Coronation gulf), Moore bay, Barry island, south side of Arctic sound (Bathurst inlet).

21. Rough Seal. *Phoca hispida* (Schreber).
    ad. ♀, June 10, Flaxman island, Alaska.
    ad. ♂ ♀, July 13, 19, Bernard harbour, Young point.
    ad. skulls, sex unknown, Bernard harbour.

22. Bearded Seal. *Erignathus barbatus* subsp ?
    ad. ♂ ♂ ♂ ♂ ♀ ♀ ♀, April 18, 23, 24, 25, May 2, 26, July 4, Chantry island, Bernard harbour (Dolphin and Union strait), Detention harbour (Bathurst inlet).
    juv. ♂ ♀, April, Chantry island, Dolphin and Union strait.
    ad. ♂, skull, July 6, Cockburn point.

22 species, 354 specimens, in 1916 accessions from C. A. E.
13 species, 77 specimens, in 1914 accessions from C. A. E.
Total accessions of specimens of mammals from the Canadian Arctic expedition, 431 specimens, 1913–1916.

Fishes and Invertebrates.

(*Frits Johansen.*)

While with the Canadian Arctic expedition I did most of my work on the fishes and invertebrates, from our ship and at various points from Vancouver island, through Bering sea and along the Alaskan and Canadian Arctic coasts east of Coronation gulf and Bathurst inlet. Some localities were only points of fleeting visits but others allowed of more prolonged and intensive study. Most of the work was done between Port Clarence on the west and Bathurst inlet on the east; and at various points very large collections were made of marine and

freshwater fishes, besides marine, freshwater, and terrestrial invertebrates of all orders down to microscopic forms.

Besides merely collecting these animals I have as far as possible studied their appearance, habits, development, and food, and made many coloured drawings from live specimens in the field. The work was not confined to the summer months but continued throughout the year, varying in methods and subject according to season. The resulting mass of material has been most interesting and unique considering the difficulties of the country.

During the summer of 1915 and since my last published report, a rich and varied collection of freshwater and land invertebrates of all sizes was made in the vicinity of Bernard harbour, N. W. T., supplemented by material obtained by J. J. O'Neill and J. R. Cox along the south of Coronation gulf, and by D. Jenness at various localities on Wollaston peninsula north of Dolphin and Union strait. Many marine and freshwater fishes were collected in the vicinity of Bernard harbour, and particular attention was paid to securing series showing age and sexual differences, and to their food. Some fishes were collected by R. M. Anderson in Coronation gulf and Bathurst inlet. A large and varied amount of material was also secured by incidental dredgings in and about Bernard harbour out to a depth of about 50 fathoms. This is the first representative marine collection ever secured on the Canadian Arctic coast west of Hudson bay. To supplement this, in the autumn a sounding survey was completed of the inner and outer harbour at Bernard harbour and of three large lakes nearby, and samples were taken of the marine and freshwater plankton throughout the year.

In March, 1916, I made a sledge trip north and east along Wollaston peninsula where I collected a few marine specimens and made some observations concerning the insects.

The summer of 1916 up to the time of leaving, July, was spent supplementing the Bernard Harbour collection of fishes and terrestrial invertebrates; and during the course of the work many new forms or those hitherto poorly represented in our collections were obtained. During the return trip from Bernard harbour to Nome advantage was taken of every suitable stop to collect marine and terrestrial invertebrates and fishes. Insect collections were made at Nome and various places in southern Alaska, as opportunity offered, and in Jasper park, Alberta.

All specimens, notes, etc., which I obtained have been safely brought to the Museum of the Geological Survey of Canada, Ottawa.

ENTOMOLOGY.

(*By C. Gordon Hewitt, D.Sc., Dominion Entomologist, Honorary Curator.*)

The congestion and restriction of available space in the Museum caused by the temporary use of the building by Parliament rendered it impossible to continue our plans for arranging the national collection of insects in the steel cabinets that have been provided for its accommodation.

In the absence of the working room required for consultation and of a qualified man in charge of the collection in the Museum, it was considered advisable to postpone further efforts to transfer to the cabinets in the Museum the main and working portion of the insect collection that is now housed in the offices of the Entomological Branch of the Department of Agriculture until the Museum is vacated by Parliament, when normal conditions will again prevail and the necessary space will be available. Our work in the Museum, therefore, has been confined to the task of transferring to the cabinets for safe storage the insects belonging to various collections that had been purchased by or donated

to the Museum in the past and which were contained in a miscellaneous collection of storage boxes and cabinets.

The main collection of insects is still in the office of the Entomological Branch and not only have considerable additions been made to it through the field work of the officers of the Branch and gifts of other collaborators, but very satisfactory progress in the identification and arrangement of the large accumulation of unclassified material can be recorded.

During the year a valuable collection of insects of British Columbia was donated by Mr. Tom Wilson, an officer of the Entomological Branch. The collection belonged to Mr. Wilson and Mr. A. H. Bush, a former employee of the Branch who was killed last year in France. Representing as it does the joint work of many years of two keen collectors it is an addition to the national collection of the greatest value, and I should like to take this opportunity of thanking Mr. Wilson again for his public-spirited action.

The insects collected on the Canadian Arctic expedition (1913-1916) by Frits Johansen have now been sorted out, pinned, and prepared for identification and steps are being taken to have the material identified and described by officers of the Entomological Branch and other specialists.

In concluding this brief statement I wish to take the opportunity of thanking Dr. L. O. Howard, Chief of the Bureau of Entomology, of the United States Department of Agriculture, Washington, D.C., for the assistance that he and his assistants in the Bureau and in the United States National Museum have continued to render us.

ANTHROPOLOGICAL DIVISION.

PART I.

ETHNOLOGY AND LINGUISTICS.

(*E. Sapir.*)

Museum.

Exhibits.

Owing to the occupation of the Victoria Memorial Museum building by the Dominion Legislature, the hall of Canadian anthropology has had to be closed to the general public. There is, therefore, nothing further to report in regard to anthropological exhibits.

Accessions of Ethnological Specimens.

The economy enforced by war conditions has made it necessary for the Geological Survey to restrict itself to the purchase of a relatively small number of ethnological objects. Aside from D. Jenness' Eskimo material, the total number of ethnological specimens obtained either by gift, by purchase in the course of regular field work of the division, or by purchase of material not obtained directly in connexion with field work, barely exceeds one hundred. A large shipment was obtained, in the course of the year, of ethnological and archæological material, resulting from the Canadian Arctic expedition, D. Jenness, the anthropologist of the expedition, being the collector. This Eskimo collection is a very extensive one and illustrates every aspect of the life and customs of the natives of Coronation gulf and neighbouring regions. As the material has not yet been completely catalogued, it is impossible to state the precise number of museum specimens that it includes, but a preliminary survey points to about 2,500 ethnological objects.

The gifts embrace:

From F. G. Speck, Philadelphia, Pa.:
- 1 Penobscot wampum collar (reproduction).
- 1 Tuscarora beaded pouch.
- 1 Alaskan Eskimo knife sheath.
- Fragments of shell illustrating wampum manufacture.

From F. Johansen, Canadian Arctic expedition:
- 1 unfinished Tlingit plaque from Alaska.

The ethnological specimens obtained in the course of regular field work for the Survey are as follows:

By F. W. Waugh:
- 39 Ojibwa specimens (including birch-bark canoe) from Nipigon district, Ont.

By J. A. Teit:
- 161 Tahltan specimens.
- 54 Thompson River specimens.
- 2 Lillooet specimens.
- 1 Tlingit specimen.

By D. Jenness, Canadian Arctic expedition:
2,500 Eskimo specimens (number only approximate, including three kayaks).

Ethnological specimens purchased otherwise than in the course of field work embrace:

From F. G. Speck:
5 Penobscot wampum belts (reproductions).
1 Kootenay pelican skin coat.

From Mrs. Michel Buckshot, Maniwaki, Que.:
2 Algonquin silver ornaments.

From C. B. Barton, Nass river, B.C.:
3 Tlingit spruce root baskets.

From Mrs. Catherine Silver, Oshweken, Ont.:
11 Iroquois beadwork articles.

Exchange of Ethnological Material.

There have been sent to Château de Ramezay, Montreal, Que., 15 Iroquois specimens, in exchange for which we have received Hochelaga skeletal material from Westmount, Que.

Photographic and Draughting Work.

The gifts of photographs of ethnological interest embrace:

From F. W. Waugh:
39 Algonquin prints from Maniwaki, Que.

From F. G. Speck, Philadelphia, Pa.:
4 Micmac photographs from Newfoundland.

From William Beynon, Port Simpson, B.C.:
2 Tsimshian photographs.

Ethnological photographs taken for the Survey by members of the anthropological staff and by the photographic department embrace:

By F. W. Waugh:
208 Ojibwa photographs from Ontario.
46 Iroquois photographs from Ontario.

By H. I. Smith:
1 Sioux photograph from Manitoba.
4 Carrier photographs from Bulkley river, B.C.
64 Tsimshian photographs from British Columbia.
10 Coast Salish photographs from Nanaimo, B.C.

By J. A. Teit, Spence Bridge, B.C.:
137 Tahltan photographs from British Columbia.
74 Thompson River photographs from British Columbia.
15 Shuswap photographs from British Columbia.
9 Okanagan photographs from British Columbia.
8 Lillooet photographs from British Columbia.
1 Chilcotin photograph from British Columbia.
3 Pend-d'Oreille photographs from Washington, U.S.A.

By D. Jenness, Canadian Arctic expedition:
251 Eskimo photographs.

By G. H. Wilkins, Canadian Arctic expedition:
11 Eskimo photographs.

By photographic division:
15 photographs of Micmac museum specimens.
5 " " Dakota Sioux museum specimens.
2 " " Chilcotin museum specimens.
61 " " Thompson River museum specimens.
3 " " Interior Salish Indians (delegation at Ottawa).
5 " " Thompson River Indian (delegation at Ottawa).
5 " " Upper Kootenay Indian (delegation at Ottawa).
3 " " Okanagan Indian (delegation at Ottawa).
6 " " Shuswap Indians " " "
9 " " Lillooet " " " "
9 " " Tsimshian " " " "
2 coloured plates of Upper Kootenay chief.
1 coloured plate of Upper Thompson River chief.

There have been received from members of the Survey not connected with the division of anthropology:

From E. L. Bruce:
8 Cree photographs from Saskatchewan.

From H. C. Cooke:
2 Ojibwa photographs from lake Mattagami, Ont.

From C. W. Drysdale:
2 Chilcotin photographs from Bridge river, B.C.

From E. M. Kindle:
4 Stoney photographs from Alberta.

The drawing of specimens and other anthropological data illustrating the publications of the division has been the work of O. E. Prudhomme, the artist of the anthropological division.

Phonograph Records.

Phonograph records received in the course of the year as a result of ethnological field work undertaken by the Survey embrace:

From J. A. Mason:
4 Mackenzie Eskimo records.
5 Chipewyan records.
3 Yellow Knife records.
20 Dog Rib records.
7 Slavey records.
1 Loucheux record.
9 Sekanais records.

From J. A. Teit:
4 Upper Thompson records (taken in Ottawa during Interior Salish delegation).

From F. W. Waugh:
1 Kootenay record (taken in Ottawa during Interior Salish delegation).
2 Thompson River records (taken in Ottawa during Interior Salish delegation).
1 Nass River record (taken in Ottawa during Interior Salish delegation).

From D. Jenness, Canadian Arctic expedition:
92 Eskimo records.

From C. M. Barbeau:
168 French Canadian records.

Field Work and Research.

Anthropological Data Obtained from a Deputation of Indian Chiefs Visiting Ottawa.

In April and May, 1916, a deputation of two Nass River chiefs, one from Ayansh, the other from Kincolith, as well as a deputation of chiefs of some of the interior tribes of British Columbia (three Shuswap, one Upper Lillooet, one Lower Lillooet, one Thompson River, one Okanagan, and one Kootenay), under the care of J. A. Teit, of Spence Bridge, B.C., visited Ottawa on government business. The opportunity was taken by the anthropological division to obtain such anthropological information as the time at the disposal of the Indian chiefs made feasible. The results were gratifying.

Rather full data on relationship terms were obtained from six of the chiefs by E. Sapir. The tribes investigated were Thompson River, Lillooet, Shuswap, Okanagan, Kootenay, and Nass River.

The presence of two well-informed Nass River chiefs from distinct villages proved a good opportunity for C. M. Barbeau to supplement the intensive study of Tsimshian social organization that he had already undertaken in the field. The informaton obtained on three of the Nass River tribes includes plans of their villages; lists, arranged according to rank, of the families and of their subdivision into houses; lists of crests belonging to each; the origin and relationship, where possible, of each family with foreign tribes; and the mapping of their hunting, fishing, and fruit-gathering lands. In a few cases lists of individual names were also taken down. Mr. Barbeau also secured some special information from the Thompson River chief on the subject of tribal and individual property.

F. W. Waugh obtained detailed descriptions of several Nass River games, including lehal, and collected several interesting Lillooet, Kootenay, Okanagan, and Thompson River string figures. He also recorded a number of lehal songs.

The visit of the Indians was also fruitful for physical anthropology. A detailed series of physical measurements was taken on nine of the chiefs by F. H. S. Knowles. Front, three-quarters, and profile views were taken of each individual, and special photographs of the Thompson River, Kootenay, and Nass River chiefs in full tribal costume. Of the Thompson River and Kootenay chiefs, also, colour plates were taken. Finally, face masks were made of the three Shuswap chiefs and the Lower Lillooet delegate, while head and shoulder casts were taken of the Kootenay and Thompson River Indians.

Field and Office Work.

In the course of the year E. Sapir continued work, begun in the past, on the large collection of Nootka family and origin legends obtained during the field trips of 1910 and 1913 and as manuscripts forwarded by Alex. Thomas. It is intended to publish this large body of material as a set of annotated texts with

free translations. At least one of the longer legends will also be given with interlinear translation for the benefit of linguistic students. The legendary texts, not including free translations, which have been prepared only in small part, cover about 950 typewritten pages. Following the legends there will be other text collections dealing with mythological tales, that do not refer to specific families or ceremonies, and with a large number of topics of ethnological interest, such as rituals, potlatching, and marriage. These text collections are intended to serve as a solid basis for the systematic discussion of various aspects of Nootka culture, to follow in the form of special memoirs. The memoirs are to be based partly on the texts themselves and partly on the extensive ethnological notes taken in the field trips already referred to. The notes relating to Nootka religion have been classified and a preliminary paper on Nootka religion, giving a brief bird's eye view of the subject, has been begun. Mr. Sapir also devoted a considerable amount of time to work on various problems of American Indian linguistics.

C. M. Barbeau spent about three months of the summer season on the north shore of the St. Lawrence river (Charlevoix and Chicoutimi counties) in the continuance of researches previously begun on French Canadian folk-lore. This trip was an unusually successful one, 128 folk tales being added to his already extensive collection. A special feature of the trip was a collection of French Canadian folk songs, about 500 of these being recorded in text, in most cases also on the phonograph. In the office Mr. Barbeau devoted a considerable share of his attention to the preparation of French Canadian folk-lore for publication. Two volumes were gotten ready for press. One of these has been already published in the course of the year by the American Folk-Lore Society in their quarterly journal; the second is to be published in one of the 1917 numbers of the same journal. Mr. Barbeau has also been engaged in the preparation of an extensive study of the property rights and potlatch transactions among the natives of British Columbia, on the basis of his own manuscript Tsimshian data, Mr. Sapir's manuscript Nootka data, and all other available information on the west coast Indians. So far Mr. Barbeau's work has been compilation and classification; the actual writing of the text of this report is to begin at the earliest opportunity.

F. W. Waugh undertook a summer field trip of about three months among the Ojibwa of northern Ontario, the first point visited being Long lake, in Thunder Bay district. Interesting information was obtained there on material culture, folk-lore, and medicine. From sixteen to eighteen folk or mythological tales were incidentally recorded. A special study was made of working methods in connexion with various handicrafts, photographs being taken whenever practicable. A particularly complete series of the latter represent canoe making, snow-shoe making, food preparation, and tanning. At lake Helen (Nipigon river) work along various lines, such as games, medicine, and folk-lore was conducted; also at Manitoulin island, which was visited next. This locality was found to be an excellent field for many kinds of information, though deficient in some, such as social organization and religion. A number of very good specimens were obtained at the various points visited.

P. Radin continued to work up his manuscript on Ojibwa data for publication in the Survey series. Most of the time was taken up with the writing out of the large body of Ojibwa mythological texts previously obtained. Work was also continued on a special monograph on Ojibwa religion, previously begun, and preparatory work was further undertaken for the preparation of a general study of the religion of the North American Indians, which is to be eventually published as a memoir by the division.

J. A. Teit's survey activities for the year consisted largely in the preparation of his extensive series of Tahltan and Kaska mythological tales. These are

liberally annotated and are practically ready for publication. Mr. Teit has also continued taking photographs of ethnological interest whenever opportunity presented itself. Under Mr. Knowles' direction he has also taken anthropometric measurements among a number of tribes of British Columbia.

The general scientific results of the Canadian Arctic expedition, insofar as they refer to anthropology, are outlined in Mr. Jenness' report subjoined below. Since his return from the field, Mr. Jenness has begun to prepare his anthropological report on the Eskimos of northern Alaska and on the Copper Eskimo of Coronation gulf and environs. He has already finished the preparation of the folk-lore, part of which is in text. The report on the physical anthropology of the Eskimo has made good headway. It is Mr. Jenness' plan to write a general paper on the culture of the Eskimos that he has studied; the introductory chapter on the physiography of the Eskimo habitat is already completed.

Ethnological Results of the Canadian Arctic Expedition.

(*D. Jenness.*)

The disaster which overtook the expedition at the very beginning of its career, when the Karluk was carried away in the drifting ice, left but one ethnologist to do the work for which two had originally been appointed. Consequently, instead of confining my attentions to the archæology, technology, and physical anthropology of the Arctic Eskimo, I found it necessary to take up also their language and sociology. Unfortunately I had never received any special training in linguistics. Moreover the first winter, owing to ice conditions, had to be spent in northern Alaska, among Eskimos who had already come under the influence of civilization and been the subject of special study by at least one ethnologist. It was not until the following year, in the late summer of 1914, that the southern party of our expedition reached its intended base amongst the Copper Eskimos, so that barely two years were available for work amongst them—the only branch of the Eskimo race which still retained its primitive mode of life unaffected by the great world beyond.

For the archæologist the country of the Copper Eskimos is barren ground. The people are migratory, with no permanent habitations; their winter settlements are merely assemblages of snow huts that melt and disappear in spring; in summer they live in tents of seal or caribou skin of which no traces remain save rings of stones which anchored down their edges. The dead are laid out on the surface of the ground and the remains scattered or destroyed by the ravages of the seasons and by the depredations of the ravens and the foxes.

On the Arctic coast of Alaska the case was different. There the natives built permanent homes of wood, and buried their dead beneath piles of logs. The ruins of their settlements can be found all along the shore. Extensive excavations were made at Barter island on the sites of three settlements and a large number of ethnographical specimens unearthed which throw a flood of light on the condition of the Eskimo in this region long before the earliest explorers came to visit its shores. When the expedition was returning south further archæological specimens were purchased at Barrow and point Hope. It will be interesting to compare these with the specimens from Barter island. In those early days iron was unknown; all weapons were pointed with horn, bone or ivory, with flint, slate, or more rarely jade. The two most important pursuits of the natives were whaling and caribou hunting. Pipes and fish nets had not then been introduced; labrets were found, however; but whether any were yielded by the

ruins that appeared oldest at Barter island has not yet been determined. Fragments of pottery were numerous: in fact the knowledge of how it was made still persists amongst the Eskimos of this region.

My anthropometrical instruments were lost on the *Karluk* and could not be replaced until 1914. Some 130 Copper Eskimos were measured, all adults, and descriptions taken of the character of the hair, eyes, cheekbones, etc. Most of this work was done in their snow huts during the winter months, when the scattered bands congregate together on the sea ice. In consequence, apart from the stature, body measurements were unattainable. Nothing was observed which would indicate fusion with any other race, save that in two or three instances the features seemed to have a somewhat Indian cast. Light coloration in the eyes and beard which were noticeable in certain individuals seemed entirely due to secondary causes. A large number of photographs illustrating the physical features of the natives were taken both by myself and by Mr. Wilkins, the photographer of the expediton.

Special attention was paid to the material culture of the Copper Eskimos and a large collection of their weapons, household utensils, and clothing was made. These are rapidly being changed through the influence of the western Eskimos and of the whites. Already the natives have an abundance of iron to replace their copper, rifles are beginning to supersede bows and arrows, European pots and tin cans take the place of stone pots, garments of cloth are in great demand, and even the style of the clothing is undergoing change. For this reason a special endeavour was made to procure numerous specimens of those objects which were most likely to suffer modification or disappear entirely.

Although the time spent amongst the Alaskan Eskimos was very brief, more success was attained in the study of this dialect than in that of the Copper Eskimos. At Barrow I was fortunate in securing for two months the services of a half-caste boy whose knowledge of English was much greater than that of the average of his class. A few folk-lore stories were written down in the native tongue, and a grammar worked out in considerable detail, accompanied by a small vocabulary. Amongst the Copper Eskimos, where no interpreter was available who possessed a knowledge of that dialect, the notes on grammatical structure are far less complete. Here, however, a large number of native songs, both the ordinary dance songs and magic incantations, were reported on a phonograph, and these have all been transcribed and translated. Amongst them are records of two shamanistic utterances, the oracles of the most powerful shaman in the region; throughout the records can be distinctly heard the running commentary maintained by his wife in the background.

The Copper Eskimo dialect would appear to be more akin to the dialect of the Mackenzie River natives than to that of Labrador; but, as in Baffin island, so too amongst the Copper Eskimo there is a constant employment of nasal terminations instead of the proper grammatical endings. Another peculiarity of the Copper dialect is the continual substitution of the conjunctive mood for the simple indicative, an anomaly which proved quite a stumbling-block at first to the Mackenzie River natives in our employ. A number of Alaskan folk-lore stories were obtained in English and a lesser number from Coronation gulf. It would appear that not only is the material culture of the Copper Eskimos much simpler than that of the western natives, but their mythology and folk-lore is also much less varied and complete. It is not merely that the actual number of the legends known to the native is less, but even those which are known seem often but the surviving fragments of others which are recorded in a more complete form elsewhere.

Much information was obtained concerning the daily life of the natives in summer and winter, both by direct inquiries, but mainly by living in their midst

observing and taking part in the common routine. Much misapprehension has existed amongst ethnologists concerning their summer life, our knowledge of which has hitherto depended entirely on the statements of travellers who have come into momentary contact with them during their wanderings. I spent seven months, from early spring till the beginning of the ensuing winter, with a small band of natives on Victoria island, sharing their life in all its details, living in the same tents, hunting and fishing with them to obtain our common food, and accompanying them in all their movements. The information thus acquired proved beyond doubt that the old theories concerning their social and religious life during this period are entirely erroneous, at least so far as this branch of the Eskimo race is concerned. While it is difficult, perhaps impossible, for a civilized person fully to understand the mental attitude of a savage people towards the phenomena of life, yet the many shamanistic performances which I witnessed and in many cases took part in, leave a general notion concerning their religious life which cannot be far from the truth. Broadly speaking, just as in Hudson bay, so here, too, a distinction is made between denizens of the sea and of the land, which is revealed in practice in the form of taboos. But the distinction is by no means rigid, and many game taboos seem to be entirely independent, in some cases even contradictory.

Manuscripts and Publications.

Manuscripts Received.

There have been received as gifts:

From J. A. Teit:
Manuscript book belonging to Cowichan prophet; drawings supposed to represent dreams and songs. Collected from Chief Paul (Hehena) of Spuzzum, B.C. (MS. 78).

From F. G. Speck:
Map of Mistassini hunting territories.
2 sketch maps of Montagnais country.

Manuscripts turned in to the division as a result of field work undertaken under the auspices of the Geological Survey include:

By E. Sapir:
"Time perspective in aboriginal American culture, a study in method," manuscript of 115 pages (MS. 74).

By C. M. Barbeau:
"Tsimshian and Iroquoian phratries and clans," manuscript of 32 pages (MS. 73).

By J. A. Teit:
"Tahltan and Kaska tales," manuscript of 220 pages (MS. 75).

By W. H. Mechling:
"Malecite ethnology," manuscript of 399 pages (MSS. 76, 76a).

By W. D. Wallis:
"Dakota ethnology" (cont.), manuscript of 371 pages (MS. 69a).

Ethnological manuscripts purchased in the course of the year embrace:

From Alex. Thomas, Alberni, B.C.:

"Origin of the Wolf Ritual," Nootka text, manuscript of 155 pages (MS. 50t).

Drawing book No. III, with ethnological notes, 26 pages (MS. 50u).

"The power of a whaler's hi·'tałukcitł'yak spell," Nootka text, manuscript of 292 pages (MS. 50v).

"Ḥa·yu·tcictu·ł, chief of Tci·qtlis'atḥ, challenges Ci·nołqa·ya, chief of Qa·'yu·k̓watḥ," Nootka text, manuscript of 26 pages (MS. 50w).

"Whaling 'o·simtc secrets of K!wats!itaqsuł of Ḥo·tcuqtłis'atḥ," Nootka text, manuscript of 101 pages (MS. 50x).

From Jacob Hess, Six Nations, Ont.:

Iroquois mythology, manuscript of 165 pages (MSS. 77–77e).

From William Beynon, Port Simpson, B.C.;

Ethnological field notes from the G̑itxała tribe of Tsimshian, manuscript of 280 pages and 2 maps (MSS. 80–80e).

Manuscripts Submitted for Publication.

In the course of the year the following papers have been submitted to the Deputy Minister of Mines for publication by the division:

E. Sapir:

"Time perspective in aboriginal American culture, a study in method" (memoir).

C. M. Barbeau:

"Tsimshian and Iroquoian phratries and clans" (bulletin).

P. Radin:

"Social and religious customs of the Ojibwa of southeastern Ontario" (memoir).

Anthropological Publications.

The following memoirs have been published in 1916:

F. W. Waugh:

"Iroquois foods and food preparation" (Memoir 86, Anthropological Series No. 12).

E. Sapir:

"Time perspective in aboriginal American culture, a study in method" (Memoir 90, Anthropological Series No. 13).

PART II.

ARCHÆOLOGY.

(*Harlan I. Smith.*)

Exhibits.

The archæological exhibits have been undisturbed by the occupation of the museum building by Parliament and are available to such of the public as are admitted to the building on application to a museum officer.

A selection of specimens illustrating aboriginal Canadian ceramics was made up and loaned to the ceramic laboratory of the Mines Branch to aid that branch in designing pottery made from Canadian clays in an effort to promote our clay industries.

Accessions.

The chief accessions to the archæological collections are as follows:

Collected by Officers of the Department.

Accession 183. About 4,000 archæological specimens from the Arctic coast of Alaska. Collected by the Canadian Arctic expedition.

Accession 184. Collection of archæological specimens from Barter island, north Alaska. Collected by the Canadian Arctic expedition.

Presented.

Gifts were received as follows:

Accession 179. Fragments of Algonkian pottery from the surface near Grand river, in the vicinity of Brantford, Ont. Presented by G. N. Waugh, Brantford, Ont., through F. W. Waugh.

Accession 180. Pipe made of stone, from a point about 100 feet north of Wellington street and about 750 feet west of Bank street, Ottawa. Collected and presented by Mr. Thomas Shore, Ottawa.

Accession 181. Hammerstone, potsherds, and chips of stone, from NW. $\frac{1}{4}$ sec. 18, tp. 15, range 13, W. 1st mer., near Arden, Man. Collected and presented by John N. Foreman, Arden, Man.

Accession 182. Point chipped from red argillite for an arrow or knife, from a point within 500 yards of the Quaco head, St. John county, N.B. Presented by Charles Brown, St. Martins, N.B.

Field Work and Research.

Mr. W. J. Wintemberg examined two Iroquoian village sites near Aylmer, Elgin county, Ont., and the Iroquoian earthwork and village site, where graves have been dug up, near London, Ont. As this proved to be of a culture different from the Iroquoian site at Roebuck in Grenville county, to have deep deposits of refuse containing archæological specimens, and to have been but slightly disturbed, being mostly covered with woods, Mr. Wintemberg considers it the best place for our next intensive exploration in Ontario.

He made notes for the files of archæological data, regarding specimens at St. Thomas and London and compiled data for his monograph on ossuaries from literature in the Toronto public library. He secured an original catalogue of the Price collection from D. H. Price of Alymer, Ont. This supplies certain information of which we were in need and will enable us to complete the cataloguing of some specimens.

Office Work.

A monograph on the archæology of Merigomish harbour, N.S., has been completed by Mr. Smith, and Mr. Wintemberg has begun compiling a monograph on ossuaries or bone-pits.

The cataloguing of the archæological specimens has been brought up to October 25, 1916 (accession 183) except for a few specimens lacking data as to the locality from which they came and a very few specimens from foreign regions for which no catalogue has been opened. The present condition of the catalogues is detailed in the following statement.

List of Catalogue Entries of Archæological Specimens.

Catalogue VIII–A	Newfoundland	vol. I	Nos. 1 to	15
VIII–B	Nova Scotia	vols. I to II	Nos. 1 to	1,276
VIII–C	Prince Edward Island	vol. I	Nos. 1 to	30
VIII–D	New Brunswick	vol. I	Nos. 1 to	57
VIII–E	Quebec	vol. I	Nos. 1 to	191
VIII–F	Ontario	vols. I to VI	Nos. 1 to	15,587
IX–A	Labrador	vol. I	Nos. 1 to	54
IX–B	Ungava	vol. I	Nos. 1 to	42
IX–C	Keewatin (coast)	vol. I	Nos. 1 to	45
IX–D	Mackenzie (coast)	vol. I	Nos. 1 to	135
IX–F	Alaska (Eskimo area)	vols. I to III	Nos. 1 to	3,710
X–A	Manitoba	vol. I	Nos. 1 to	423
X–B	Saskatchewan	vol. I	Nos. 1 to	23
X–C	Alberta	vol. I	Nos. 1 to	29
XI–A	British Columbia (interior)	vol. I	Nos. 1 to	1,085
XI–B	Yukon (interior)	vol. I	Nos. 1 to	3
XI–C	Mackenzie (interior)	vol. I	Nos. 1 to	5
XI–D	Keewatin (interior)	vol. I	Nos. 1 to	10
XII–A	Washington and Oregon (coast)	vol. I	Nos. 1 to	47
XII–B	British Columbia (coast)	vol. I	Nos. 1 to	620
	Total entries			23,387

Some of these entries, such as those of similar objects from one place, for instance, fragments of pottery and points for arrows, cover as many as twenty-six specimens.

Catalogue of Archæological Photographs, Negatives, and Lantern Slides, Vol. I.

This catalogue is arranged numerically and the numbers correspond to those of the photographic division of the Survey.

The address list of persons said to have collections of Canadian archæological specimens, practically all of these being residents of Canada, now totals over one hundred and fifty. They are arranged alphabetically by name and cross indexed by locality.

Archæological Data File.

Many additions have been made to the file of archæological data. This now fills one steel cabinet. That arranged by provinces and counties, and by names of special places, now fills more than two drawers. It includes maps, drawings, photographs, memoranda, and more or less complete manuscript regarding archæological sites, specimens, and similar archæological matters in Canada. These data, as indicated by the labelling on the drawers, are arranged in groups with signals, as follows: Arctic, Newfoundland, Prince Edward Island, Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia interior, British Columbia coast. The names of provinces for many of these groups are again subdivided in folders under the names of counties. Copies of some of this material are filed alphabetically under the names of special places as well as in the above-mentioned folders. Manuscripts regarding areas or localities, in process of writing or complete, are also kept in this file. Memoranda of what archæological evidence has been found or what sites exist in a

certain place may be found in one of these groups. Before going to the field to explore, a field party may consult or copy the data in the folders covering the areas to be visited.

Carbon copies or duplicates of the above mentioned material are arranged as a cross reference by a table of contents or evidences, and by names of special kinds of antiquities. This material fills two additional drawers. Information on any archæological subject, as contrasted with the archæology of any place or region, may be found in the folders in these latter drawers; a petroglyph described in a folder under the province of British Columbia is represented in this file by a carbon copy in a folder for petroglyphs. These folders are arranged according to a table of contents, practically such as is frequently used in publications, and a copy of which is kept in the first folder in this file.

Certain other material of this character is filed under names of special kinds of artifacts and in alphabetical order For instance a subject like wampum is found in this file under wampum behind a signal lettered Wa, as well as in the table of contents folder under "shell" and under "shell bead". Manuscripts regarding subjects, in process of writing or complete, are also kept in this file.

The card bibliography of the archæology of Canada, which is arranged by author, has been added to regularly.

PART III.

PHYSICAL ANTHROPOLOGY.

(*F. H. S. Knowles.*)

Accessions.

The following material coming under the head of physical anthropology has been obtained by members of the division of anthropology:

By F. H. S. Knowles:

- 40 face casts, unmasked, Central Eskimo natives of Hudson bay (casts received from Captain Comer in 1910).
- 2 pairs of hands, cast from Central Eskimo natives of Husdon bay, unmasked (casts received from Captain Comer in 1910).
- 2 face casts, unmasked, Central Eskimo natives of Hudson bay (taken originally by A. P. Low in 1904, and cast by Captain Comer).
- 9 anthropometric schedules of interior British Columbia and Nass River Indian chiefs on deputation to Ottawa, May, 1916.

By F. W. Waugh:

- Head and shoulder plaster mould of Chief Paul David, Kootenay, B. C.
- Head and shoulder plaster mould of Chief Tetlenitsa, Thompson river, British Columbia.
- Face mould of Chief Elie LaRue, Shuswap, B. C.
- Face mould of Chief Basil David, Shuswap, B. C.
- Face mould of Chief Adolph Thomas, Shuswap, B. C.
- Face mould of Willie Pascal, Lower Lillooet, B. C.

Casts from the five moulds enumerated above were made in the course of the year by F. H. S. Knowles.

The following skeletal material has been received through W. D. Lighthall, Westmount, Que., from Château de Ramezay, Montreal, Que., in exchange for Iroquois ethnological material forwarded to that museum:

Iroquoian skeletal material from "a Hochelaga burying ground," Westmount, Que.

GEOGRAPHICAL AND DRAUGHTING DIVISION.

(*C.-Omer Senécal.*)

During the past year, one map compiler, Joseph Edouard Paquet, died a few months after his appointment, and another, Stanley G. Alexander, was detached for overseas service with the Canadian Expeditionary force. Notwithstanding this reduction in the staff, and although work on certain maps of a special character requiring the continued attention of skilled compilers had, in consequence, to be suspended, satisfactory progress was made in the routine of the division. The work is being carried on by eleven persons, including the chief in charge, his assistant, eight compilers and draughtsmen, and two clerks.

Thirty-three new maps were completed during the year, and were sent to the Government Printing Bureau for reproduction. Twenty-eight more are, at present, at various stages of compilation or preparation for engraving and printing. Besides the above, 165 sketch maps, diagrams, sections, text figures, and miscellaneous drawings, were executed for the illustration of Geological Survey memoirs and bulletins, or for use by the field staff or museum staff.

Two manuscript advance maps were supplied to accompany special reports on road materials available for certain highways in Ontario and Quebec.

A special edition of the map of Canada and United States, was also printed for the use of the biological division.

The correspondence shows a total of 1,201 letters, reports, specification sheets, memoranda, etc., sent out during the year, while 596 were received.

Much time, as usual, was devoted by the chief of the division to duties in connexion with the Geographic Board of Canada, on which he is one of the Geological Survey representatives.

The maps listed below were, at the end of the year, in the hands of the King's Printer, for engraving and printing:

Maps in Hands of the King's Printer, December 31, 1916.

Series A	Publication number	Title	Date of requisition
46	1246	Kirkfield, Ont., contour map	Apl. 18, 1914.
57	1223	Frank landslide, Alberta, contour map	Feb. 21, 1916.
60	1231	Wheaton area, Y.T.	Apl. 29, 1916.
63	1238	Moncton, N.B., contour map	March 1, 1915.
132	1379	Rainy River district, Ont.	June 15, 1916.
151	1540	Nansen and Victoria creeks, Y.T.	May 3, 1916.
152	1541	Kluane lake, Y.T.	May 3, 1916.
154	1552	Southwestern Yukon	May 3, 1916.
157	1567	East Sooke, B.C., contour map	Nov. 18, 1915.
161	1578	Beaverton, Ont., contour map	Feb. 14, 1916.
162	1579	Sutton, Ont., contour map	Feb. 14, 1916.
163	1580	Barrie, Ont., contour map	Feb. 14, 1916.
164	1581	St. John, N.B., contour map	March 14, 1916.
165	1582	Windermere, B.C., contour map	March 16, 1916
166	1583	Flathead coal area, B.C., contour map	Dec. 9, 1916,
174	1593	Blairmore, Alberta, contour map	March 29, 1916.
179	1621	Onaping sheet, Ont.	June 15, 1916.
180	1624	Espanola area, Ont.	Nov. 4, 1916.
182	1629	Flathead coal area, B.C., geology	Dec. 9, 1916.
186	1644	Tazin and Taltson rivers, N.W.T.	Dec. 9, 1916.
187	1645	Southern plains of Alberta, plan	Sept. 15, 1916.
...	1646	Southern plains of Alberta, perspective view of model, looking northeast	Sept. 15, 1916.
..	1647	Southern plains of Alberta, perspective view of model, looking southwest	Sept. 15, 1916.

The following is a list of forty-three new map editions published during the past year.

Geological Survey Maps Published During the Year 1916.

Series A.	Publication number.	Title.	Remarks.
		Yukon.	
59	1230	Wheaton area, scale $\frac{1}{62500}$	Topography.
178	1618	Scroggie, Barker, Thistle, and Kirkman creeks, scale 4 miles to 1 inch	Route map.
		British Columbia.	
...	1002	Special map of Rossland, scale $\frac{1}{4800}$	Geology, reprint.
...	1004	Rossland mining camp, scale $\frac{1}{14400}$	Geology, reprint.
37	1183	Beaverdell, Yale district, scale $\frac{1}{62500}$	Geology.
112	1320	Vananda, Texada island, scale $\frac{1}{24000}$	Geology.
158	1568	Nanaimo, Vancouver island, scale $\frac{1}{62500}$	Geology.
159	1569	Nanaimo, Vancouver island, scale $\frac{1}{62500}$	Superficial geology.
160	1570	Nanaimo, Vancouver island, scale $\frac{1}{62500}$	Economic geology.
175	1594	Ymir, Kootenay district, scale 1 mile to 1 inch	Geology.
176	1597	Graham island, Queen Charlotte islands, scale 4 miles to 1 inch	Geology.
177	1598	Southern portion of Graham island, Queen Charlotte islands, scale 2 miles to 1 inch	Geology.
...	1605	Limonite deposits, Limonite creek, scale 600 feet to 1 inch	Geological diagram.
...	1607	Part of northern interior of British Columbia, scale 20 miles to 1 inch	Geological diagram.
...	1608	Copper Crown group, Grouse mountain, scale 5 miles to 1 inch	Geological diagram.
...	1610	Bridge River area, Lillooet mining division, scale 3 miles to 1 inch	Geological diagram.
...	1611	Highland Valley copper camp, Ashcroft mining division, scale 4 miles to 1 inch	Geological diagram.
...	1631	Tamarac fissure vein, Ymir, Kootenay district	Geological block diagram.
...	1632	Wilcox mine, Ymir, Kootenay district	Geological stereogram.
...	1633	Porto Rico mine, Kootenay district	Geological stereogram.

		Alberta and Saskatchewan.	
...	1604	Artesian water area, southern Alberta, scale 15 miles to 1 inch....	Geology.
181	1628	Wood Mountain-Willowbunch coal area, scale 4 miles to 1 inch...	Economic geology.
		Ontario.	
...	342	Hunter Island sheet, scale 4 miles to 1 inch....................	Reprint in black only.
...	560	Seine River sheet, scale 4 miles to 1 inch......................	Reprint in black only.
...	589	Lake Shebandowan sheet, scale 4 miles to 1 inch................	Reprint in black only.
66	1235	Brechin sheet, Ontario and Victoria counties, scale $\frac{1}{62500}$..........	Topography.
67	1246	Kirkfield sheet, Victoria county, scale $\frac{1}{62500}$....................	Topography.
153	1544	Askwith and Churchill townships, scale 1 mile to 1 inch..........	Geology.
169	1586	Lines of transportation in southern Ontario, scale 35 miles to 1 inch	Route map.
170	1587	Trap deposits on north shore of lake Huron, scale 3·95 miles to 1 inch..	Economic geology.
171	1588	Road metal deposits in Essex county, scale 3·95 miles to 1 inch...	Economic geology.
172	1589	Road metal deposits in Kent county, scale 3·95 miles to 1 inch....	Economic geology.
173	1590	Sand and gravel deposits along the north shore of lake Huron, scale 3·95 miles to 1 inch...	Economic geology.
...	1599	Roebuck site, Grenville county, scale 30 feet to 1 inch...........	Archæology, diagram.
...	1600	Burials in, and near refuse heap No. 1, Roebuck site, scale 6 feet to 1 inch..	Archæology, diagram.
...	1619	Shore-lines of lake Algonquin and lake Iroquois, scale 6 miles to 1 inch..	Physiography.
		Quebec.	
148	1531	Island of Montreal, scale about 0·9 mile to 1 inch..............	Surface geology.
149	1532	City of Montreal, scale 0·4 mile to 1 inch......................	Surface geology.
156	1560	Eskimo tribes of Labrador, scale 100 miles to 1 inch............	Ethnology.
...	1609	Harricanaw-Turgeon basin, scale 20 miles to 1 inch............	Geological diagram.
184	1634	Roberval, Lake St. John county, scale 2 miles to 1 inch..........	Geology.
		Nova Scotia.	
150	1539	Ponhook lake, Sheet 72, Halifax and Hants counties, scale 1 mile to 1 inch..	Geology.
...	1606	Infusorial earth deposits, Loon Lake island, Liverpool river, Queens county, scale 500 feet to 1 inch..........................	Economic geology.

PHOTOGRAPHIC DIVISION.

(*G. G. Clarke.*)

The following is a statement of the work done by the photographic division during the calendar year 1916:

Contact prints	$3\frac{1}{4} \times 4\frac{1}{4}$ to 36×48	13,090
Bromide enlargements	4×5 to 40×72	379
Exposures developed	$3\frac{1}{4} \times 4\frac{1}{4}$ to $6\frac{1}{2} \times 8\frac{1}{2}$	2,868
Dry plate negatives	4×5 to 11×14	507
Wet plate negatives	8×10 to 24×30	163
Photo zinc plates	11×14 to 26×32	20
Proofs from zincs	11×14 to 26×32	51
Photostat copies	7×11 to 11×14	655
Lantern slides	$3\frac{1}{4} \times 4$	266
Photos and titles mounted		629

LIBRARY.

(*M. Calhoun, Acting Librarian.*)

The additions to the library during the year 1916 were as follows:

Books purchased, 415; books received by gift, 542; periodicals subscribed for, 9; periodicals re-subscribed for, 114; pamphlets received, 124; a large number of maps were also received.

Two hundred and fifty-six volumes were bound.

During this year a satisfactory map classification scheme was worked out by the library committee, and considerable progress has been made in the cataloguing and arrangement of the maps. The general cataloguing included current accessions and the re-cataloguing of many of the old volumes in the library.

Owing to the removal of the greater part of the staff of the Geological Survey from the Museum, it was found necessary to establish a small branch library in the temporary office building on Wellington street.

PUBLICATIONS DIVISION.

(*M. Sauvalle.*)

ENGLISH REPORTS.

(*James Hill, Editor.*)

The following memoirs, museum bulletins, and a summary report were published during the calendar year 1916:

1039. Memoir 87, Geological Series 73. *Geology of a portion of the Flathead coal area, British Columbia*—by J. D. MacKenzie; pp. i, ii, 1–53; plates, 1; figures, 1; maps, 2; edition, 3,000 copies; published Oct. 10, 1916.

1138. Memoir 89, Geological Series 75. *Wood Mountain-Willowbunch coal area, Saskatchewan*—by Bruce Rose; pp. i, ii, 1–103; plates, 7; figures, 1; maps, 1; edition, 3,500 copies, published Dec. 30, 1916.

1438. Museum Bulletin 24, Geological Series 33. *Late Pleistocene oscillations of sea-level in the Ottawa valley*—by W. A. Johnston; pp. 1–14; figures, 1; edition, 2,500 copies; published Oct. 2, 1916.

1591. Memoir 83, Geological Series 70. *Upper Ordovician formations in Ontario and Quebec*—by A. F. Foerste; pp. i–viii, 1–279; figures, 8; edition, 3,500 copies; published Aug. 23, 1916.

1601. Museum Bulletin 22, Geological Series 31. *The age of the Killarney granite*—by W. H. Collins; pp. 1–12; plates, 1; figures, 1; edition, 2,500 copies; published Feb. 11, 1916.

1602. Memoir 84, Geological Series 69. *An exploration of the Tazin and Taltson rivers, North West Territories*—by Charles Camsell; pp. i–iii, 1–124; plates, 18; maps, 1; edition, 4,000 copies; published July 4, 1916.

1612. Memoir 86, Anthropological Series 12. *Iroquois foods and food preparation*—by F. W. Waugh; pp. i–v, 1–235; plates, 39; figures, 2; edition, 2,500 copies; published Oct. 4, 1916.

1614. Memoir 85, Geological Series 71. *Road material surveys in 1914*—by L. Reinecke; pp. i–viii, 1–244; plates, 10; figures, 2; maps, 5; edition, 3,000 copies; published Sept. 30, 1916.

1625. *Separate* from Memoir 85; parts I and V; pp. i, ii, 1–36, 141–217, 231–235; plates, 3; figures, 2; maps, 1; edition, 500 copies; published Nov. 9, 1916.

1626. *Separate* from Memoir 85; parts I, III, and IV; pp. i–iii, 1–36, 87–137, 225–229; plates, 3; figures, 2; maps, 2; edition, 500 copies; published Nov. 9, 1916.

1627. *Separate* from Memoir 85; parts I and II; pp. i–iii, 1–83, 219–223; plates, 4; figures 2; maps, 2; edition, 500 copies; published Nov. 9, 1916.

1616. *Summary Report of the Geological Survey, Department of Mines, for the calendar year 1915;* pp. i–viii, 1–307; figures, 3; maps, 8; edition, 5,000 copies; published May 18, 1916.

1575. *Separate* from Summary Report, 1915, *Zoology*; pp. 249–264; edition, 200 copies; published May 18, 1916.

1620. *Separate* from Summary Report, 1915, *Wheaton district*; pp. 36–49; figures, 1; maps, 1; edition, 2,000 copies; published May 18, 1916.

1622. Memoir 88, Geological Series 72. *Geology of Graham island, British Columbia*—by J. D. MacKenzie; pp. i–viii, 1–221; plates, 16; figures, 23; maps, 2; edition, 3,500 copies, published Sept. 30, 1916.

1635. Memoir 90, Anthropological Series 13. *Time perspective in aboriginal American culture, a study in method*—by E. Sapir; pp. i, ii, 1–87; edition 2,000 copies; published Nov. 25, 1916.

1639. Museum Bulletin 23, Geological Series 32. *The Trent Valley outlet of lake Algonquin and the deformation of the Algonquin water-plane in lake Simcoe district, Ontario*—by W. A. Johnston; pp. i, 1–27; plates, 3; maps, 1; edition, 2,500 copies; published Sept. 27, 1916.

1642. Memoir 92, Geological Series 74. *Part of the District of Lake St. John, Quebec*—by John A. Dresser; pp. i–iii, 1–88; plates, 5; figures, 2; maps, 1; edition, 3,000 copies; published Dec. 30, 1916.

FRENCH TRANSLATIONS.

(*M. Sauvalle, Chief Translator.*)

Guide Books of the International Geological Congress, 1913. Complete series of 13 volumes. Published June 20, 1916.

1174. MEMOIR No. 20E. Gold Fields of Nova Scotia. By W. Malcolm. Published June 28, 1916.

1207. MEMOIR No. 26. Geology and mineral deposits of the Tulameen district, B. C. By C. Camsell. Published September 2, 1916.

1227. MEMOIR No. 30. The basins of Nelson and Churchill rivers. By William McInnes. Published March 3, 1916.

1281. MEMOIR No. 25. Report on the clay and shale deposits of the western provinces, part II. By H. Ries and J. Keele. Published February 23, 1916.

1291. The archæological collection from the southern interior of British Columbia. By H. I. Smith. Published June 5, 1916.

1318. MEMOIR No. 45. The inviting-in feast of the Alaska Eskimo. By E. W. Hawkes. Published February 9, 1916.

1327. MEMOIR No. 48. Some myths and tales of the Ojibwa of southeastern Ontario. By Paul Radin. Published July 20, 1916.

1389. MEMOIR No. 59. Coal fields and coal resources of Canada. By D. B. Dowling. Published March 17, 1916.

1341. MEMOIR No. 50. Upper White River district, Yukon. By D. D. Cairnes. Published August 1, 1916.

1343. Museum Bulletin No. 2, containing Geological Series 13 to 18, and Anthropological Series 2. Published July 26, 1916.

1345. Memoir No. 51. Geology of the Nanaimo map-area. By C. H. Clapp. Published October 10, 1916.

1360. Summary Report of the Geological Survey, Department of Mines, for the calendar year 1913. Published January 5, 1916.

1364. Memoir No. 53. Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia (revised edition). By D. B. Dowling. Published March 22, 1916.

1399. Memoir No. 60. Arisaig-Antigonish district. By M. Y. Williams. Published April 13, 1916.

1452. Memoir No. 64. Preliminary report on the clay and shale deposits of the province of Quebec. By J. Keele. Published June 13, 1916.

1454. Memoir No. 65. Clay and shale deposits of the western provinces, part IV. By H. Ries. Published July 20, 1916.

1456. Memoir No. 66. Clay and shale deposits of the western provinces, part V. By J. Keele. Published July 20, 1916.

1484. Museum Bulletin No. 8. The Huronian formations of Timiskaming region, Canada. By W. H. Collins. Published May 20, 1916.

1504. Summary Report of the Geological Survey, Department of Mines, for the calendar year 1914. Published February 14, 1916.

1529. Catalogue of Canadian Birds. By John Macoun. Published May 10, 1916.

ACCOUNTANT'S STATEMENT.

(*John Marshall.*)

The funds available for the work and the expenditure of the Geological Survey for the fiscal year ending March 31, 1916, were:

Details	Grant	Expenditure
	$	$
Amounts voted by Parliament	614,388.30	
Civil list salaries		193,775.77
Explorations in British Columbia and Yukon		21,511.68
Topographical surveys in British Columbia		14,985.32
Explorations in North West Territories		21,312.44
Topographical surveys in North West Territories		13,394.57
Explorations in Ontario		9,475.04
Topographical surveys in Ontario		6,328.82
Explorations in Quebec		16,614.18
Topographical surveys in Quebec		3,120.35
Explorations in New Brunswick		5,955.76
Explorations in Nova Scotia		5,224.22
Explorations in general		3,642.90
Palæontological investigations		10,320.06
Ethnological investigations		6,330.92
Archæological investigations		1,545.45
Investigations of road metals		7,970.11
Arctic expedition		549.83
Publication of reports		101,569.05
Translation of reports		5,156.25
Publication of maps		18,152.45
Wages, outside service		14,704.14
Stationery, mapping materials, and sundry printing		7,790.55
Miscellaneous		4,122.52
Specimens for Museum		4,550.92
Library		2,877.18
Instruments and repairs		2,627.67
Photographic supplies		2,205.36
Postages and telegrams		2,013.75
Advertising		1,060.32
Civil government contingencies		1,023.79
Compensation to J. F. Lyons, in lieu of quarters, fuel, and light		400.00
Balance unexpended and lapsed		104,076.93
	614,388.30	614,388.30

Summary.

—	Grant	Expenditure	Grant not used
	$	$	$
Civil government appropriation	232,362.50	193,775.77	38,586.73
Explorations and surveys in Canada	185,000.00	151,279.86	33,720.14
Publication of reports and maps; translating	125,000.00	125,000.00	
Purchase of books, instruments, miscellaneous	54,125.80	34,381.03	19,744.77
Purchase of specimens for Victoria Memorial Museum	15,000.00	4,450.92	10,549.08
Compensation to J. F. Lyons, for quarters, fuel, and light	400.00	400.00	
Civil government contingencies	2,500.00	1,023.79	1,476.21
	614,388.30	510,311.37	104,076.93

Casual Revenue.

Sales of equipment	$1,250.00	
Sales of publications	52·69	$1,302.69

I have the honour to be, sir,

Your obedient servant,

WILLIAM McINNES,
Directing Geologist.

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D.

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